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PREFEASIBILITY STUDY OF A SPACE ENVIRONMENT
MONITORING SYSTEM (SEMOS)

Prepared under Contract No. NAS 8-20082 by
Chou, Chih Kang, B. D. DeBaryshe,
A. S. Hill, and M. C. Thadani

NORTHROP SPACE LABORATORIES

For

NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama

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FOREWORD

Although this report was prepared in early 1966, it contains ideas and concepts which may still be of value in planning future aerospace environment measuring programs. The work reported was accomplished to assess the need for a space environment monitoring system and briefly develop the requirements and some possible concepts. The material contained in this report represents only pre-feasibility considerations and reflects the ideas and opinions from representatives of many private firms, universities, and government organizations at the time (March 1966). The report is published to document the effort as a contribution to future endeavors on the subject.

PREFACE

This report was prepared by the Northrop Corporation, Norair Division, Northrop Space Laboratories, Huntsville, Alabama, under NASA Contract NAS8-20082, Appendix F-1, Schedule Order 11. This Schedule Order was initiated by Mr. W. W. Vaughan, Chief, Aerospace Environment Division, Aero-Astrodynamics Laboratory, George C. Marshall Space Flight Center in February 1966. The technical coordinator for this task was Mr. R. E. Smith, R-AERO-YS. Mr. Jesco von Puttkamer, R-AERO-T, was the alternate technical coordinator. The responsible NSL engineer was Mr. J. E. Ligocki.

Acknowledgement and gratitude is extended to many technical groups and individuals in NASA, DOD, industry, universities, and scientific organizations who contributed ideas and opinions in response to the numerous queries of the study group and MSFC personnel. It is not possible to list herein each individual contacted in the process of conducting this analysis. Principal agencies and offices contacted are listed below:

National Aeronautics and Space Administration:
      NASA Headquarters, Washington, D. C.
      Marshall Space Flight Center, Huntsville, Alabama
      Manned Space Flight Center, Houston, Texas
      Goddard Space Flight Center, Greenbelt, Maryland
      Langley Research Center, Hampton, Virginia
      Ames Research Center, Moffett Field, California

Department of Defense:
      DOD, Pentagon, Washington, D. C.
      U. S. Air Force, Washington, D. C.
      U. S. Air Force, Air Weather Service, Scott AFB,
          Belleville, Illinois

Environmental Science Services Administration:
      National Environmental Satellite Center, Washington, D. C.
      Institute for Telecommunication Sciences and Aeronomy
          (ITSA), Boulder, Colorado

Universities:
   Massachusetts Institute of Technology, Cambridge, Mass.
   University of Wisconsin, Madison, Wisconsin
   University of Iowa, Iowa City, Iowa
   University of Chicago, Chicago, Illinois
   Leland Stanford Jr. University, Palo Alto, California
      (Stanford University)
   University of California, Berkley, California
   University of Miami, Miami, Florida
   Rice University, Houston, Texas
   Illinois Institute of Technology, Chicago, Illinois

Industry:
   Motorola, Inc., Scottsdale, Arizona
   Aerospace Corporation, Los Angeles, California
   TRW/Systems, Palos Verdes, California
   Northrop Space Laboratories, Hawthorne, California

Research Agencies:
   Argonne National Laboratory, Argonne, Illinois
   Lovelace Foundation for Medical Education and Research,
      Albuquerque, New Mexico
   National Center for Atmospheric Research (NCAR),
      Boulder, Colorado
   Institute of Space Studies, New York, New York
   Stanford Research Institute, Menlo Park, California
   Illinois Institute of Technology Research Institute,
      Chicago, Illinois
   Lawrence Radiation Laboratory of the University of
      California, Livermore, California
   Stanford Linear Accelerator Center, Palo Alto, California

The purpose of this report is to collect, digest, and assess the contributions received from the above organizations and, through independent analysis, evaluate the need for a space environment monitoring system and briefly develop the requirements and some possible concepts. At this time only pre-feasibility considerations are presented and it is recognized that further work in many areas, including further feasibility analyses, must be undertaken to satisfactorily develop an intelligent system concept.

Although considerable effort has been made to verify, check and edit the information and data contained in this report, the validity of the material presented cannot be assured.

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SUMMARY

The need for an Earth orbital system to continuously monitor the near-Earth and space environment and to assist in monitoring certain aspects of the Earth's atmosphere has been established. An understanding of the interrelationships between the space environment and meteorological phenomena will contribute to the development of monitoring and warning systems. In addition, other areas such as communications, reentry physics, and further experimentation will benefit from improved knowledge concerning the influence of the space environment on Earth's atmospheric environment.

A Space Environment Monitoring System (SEMOS) can be further substantiated by noting the severe technological and economic problems associated with gathering data from the ground. The vastness of space, and the inability to sample this volume continuously with ground based systems alone, indicates the required system must supplement ground station data with information from orbital spacecraft.

The requirement that an operational space monitoring system be manned has been suggested. Further technical and cost-effectiveness studies are necessary to demonstrate this clearly. As a trouble shooter, decision maker, and analyzer, man cannot be excelled by mechanical or electronic systems. Beyond a certain level of complexity, the use of man for these functions becomes almost mandatory. Thus, it is believed at

this time, that the primary role of man in a SEMOS concept will be to maintain long term reliability.

Preliminary concepts of SEMOS were developed and are presented in the report. It was shown that a reasonable concept is feasible within the framework of the Apollo Applications Program (AAP) leading to an advanced operational mission using Apollo hardware. Alternate system concepts using unmanned synchronous stations, satellite buoys and/or rocket probes or balloons show merit at this time. In general, a clear distinction between an operational monitoring system and a scientific experiment system was not apparent during the study. Considerable analysis is necessary before an intelligent SEMOS concept and its place in the national space program can be proposed.

Preliminary work toward the SEMOS goal has been initiated through the development of solar flare warning systems for both NASA and the USAF. Due to security requirements and organizational distinctions, the existence of the two separate environmental monitoring systems will continue. The systems currently being established rely on ground-based observations of the sun and the statistical development of solar flare predictions and warning forecasts. This technique is considered inadequate for the post Apollo flights. An urgent need exists for improvements in the understanding of the physical processes involved, coverage of the network, forecasting reliability, data processing, and dissemination.

It is recommended that further study by MSFC be initiated, specifically oriented toward the integration of the SEMOS with the existing NASA/ESSA and USAF warning systems and toward the development of the requirements and constraints for a program leading to a manned, semi-manned, or unmanned space environmental monitoring system. Included in this study should be the

assessment of the potential for integration with the existing AAP program. Instrumentation and data handling system studies should be the primary technical areas of greatest concern.

SECTION I.   INTRODUCTION

In the fall of 1961, President John F. Kennedy proposed a four-point program to the United Nations for the peaceful use of outer space.   The United Nations General Assembly unanimously approved a resolution embodying the proposition.   Consequently, the United States has applied its space technology to the exploration, under-standing, and utilization of the near-Earth space in support of the United Nations resolution.   Many programs are already in existence, including:

A.   Meteorological Satellites, such as TIROS, NIMBUS, and ESSA.

B.   Communications Satellites, such as ECHO, TELSTAR, RELAY, and EARLY BIRD.

C.   Geophysical Observatories, such as EGO-1, POGO, and OGO-F.

D.   Exploratory satellites, such as the Explorers, PEGASUS, and ATS.

The concept of continuously monitoring the near-Earth space environment on an operational basis as a continuation of these national efforts was originally developed at MSFC as a part of their manned space flight study activities.   For identification purposes, this specific study has been called SEMOS for Space Environment Monitoring System.   The requirements initially conceived for this system are sum-marized as follows:

A.   Become an integral part of AAP and provide support for conducting these activities.

B.   Continuously monitor the near-Earth and space environment.

C.   Rapid transmission, both automatically and upon inter-rogation, of stored and instantaneous measurements to receivers on the Earth or in manned orbiting vehicles.

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D.   Rapid analysis of telemetered data with immediate dissemination to using agencies for application in current operations and studies.

E.   Have growth potential toward an environmental monitoring space platform (possibly manned), without being dependent on succeeding steps in its operation, utility, and efficiency.

The development of such a system to achieve these objectives was conceived as an evolutionary process beginning with the utilization of standard module packages onboard AAP manned spacecraft. It would be a relatively easy step to then provide many buoy-type monitoring satellites in orbits constrained to repetitively pass over certain ground stations or relay their data to larger synchronous satellites. A further extension might result in manned stations with professional space physicists/meteorologists combined with the buoy-type monitoring satellites. The key aspect of this system development is the design and use of operational packages to meet the requirements discussed above rather than the use of experimental instruments designed for scientific data collection.

The integration with operational aspects of the AAP envisioned for this system and the relationship with the scientific community is diagrammed in Figure 1. The most important features of this program would be the close interrelationships expected with scientific research programs and the evolutionary development of the manned or semi-manned station.

In the former case, it is intended that in the early definition and development phases of a SEMOS program, the requirements of the scientific community will play an important part. By providing space onboard AAP flights, the SEMOS packages can assist in the development of instrumentation, sampling procedures, test techniques, data handling, and, more importantly, define the role of man in such activities. By maintaining close working relationships with the scientific research programs, the SEMOS program can provide considerable data and experience.

The evolutionary aspects of the SEMOS program involve the progressive steps indicated in Figure 1. The initial packages would probably be onboard experiments which would be returned or left unattended in orbit at the termination of the particular AAP flight. For longer lifetime, packages with their own power supplies and communication systems could be ejected before AAP reentry. Onboard

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POSSIBLE EVOLUTION OF ENVIRONMENTAL SCIENCES OBSERVATION CAPABILITY

SEMOS DEVELOPMENT
(Space Environment Monitoring System)

SEMOS PACKAGES ON-BOARD MANNED AAP FLIGHTS
(Saturn IB/Saturn Ⅴ, 1969-75)

STEP Ⅰ

- POSITION: Nominal AAP orbits
- READ-OUT: Continuous or on interrogation to astronaut and/or ground station(s)
- PURPOSE: Provide operational environmental knowledge in real time to crew and/or ground
- CONTINUITY: Prepare for Step Ⅱ by hardware test and checkout, and for Step Ⅲ by demonstrating man's role and performance. Will qualify Step Ⅱ and Step Ⅲ systems, procedures, operations, etc.

(a) MISSION LIFETIME

SEMOS activity terminated at AAP flight termination

(b) LONG LIFETIME

SEMOS activity continues after AAP flight. Packages ejected before AAP reentry.

(a) BUOYS IN AAP ORBITS

Ejected from AAP flights (identical with Ⅰ(b), above)

(b) BUOYS IN AAP AND NON-AAP ORBITS

Emplaced by unmanned flights.

UNMANNED SEMOS SPACE BUOYS
(Saturn IB, 1970-?)

STEP Ⅱ

- POSITION: Both in AAP and in repetitive (phased array) orbits
- READ-OUT: Continuous or on interrogation to ground and in-flight AAP systems
- PURPOSE: Provide continuous environmental monitoring for real-time operational use.
- CONTINUITY: Test and checkout hardware, ops and procedures for Step Ⅲ

SCIENTIFIC RESEARCH PROGRAMS IN ASTROPHYSICS, PHYSICAL SCIENCE, AND ATMOSPHERIC SCIENCE

(AAP Experiments and Scientific Satellites)

Requirements

Data & Capability

MANNED OR SEMI-MANNED ENVIRONMENTAL SPACE PLATFORM (Saturn Ⅴ, 1976-?)

STEP Ⅲ
- POSITION: Synchronous, stationary (24 hr) orbit. Other orbits, as required.
- PRINCIPAL FEATURES: Manned by professional operator, if feasible. Combines results and interests from all current natural environment programs. If not permanently manned, may be maintained and repaired by man.

Figure 1
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propulsion systems could then maneuver the buoys into other orbits. These independent packages could also be launched by smaller boosters into the desired orbits.

The final phase envisioned for this program would be a manned space platform or one which human crews periodically inspect and maintain (semi-manned). Considerable study efforts and analyses must be expended to evaluate this latter concept. Certain aspects of these problems are discussed in the body of this report.

Based on this preliminary concept, a pre-feasibility study was initiated to evaluate this system and further define SEMOS. The next section of this report presents the study methodology pursued.

SECTION II   METHODOLOGY

This report summarizes Phase I of the pre-feasibility study of a manned space environment monitoring system, identified as SEMOS (Space Environment Monitoring System). The analysis was divided into three phases with the decision on commencement of Phases II and III contingent on the results of the first phase. The study methodology is detailed below:

PHASE I: (6 Weeks)

Purpose: Investigate the need for continuously monitoring the space environment on an operational basis eventually utilizing a manned or semi-manned orbital station.

Procedure: Through literature surveys and personal interviews collect, digest, evaluate, and assess existing opinions and published ideas on the need for a SEMOS type system. Consider the time-frame in which such a system will conceivably be required. In this process, include the spectrum of scientific, university, military, and NASA agencies to obtain a broad outlook spanning the entire national space program. Associated with this assessment, develop a preliminary SEMOS concept and discuss the feasibility of an operational system.

Expected Results: A statement of the need and postulated time frame for an operational manned space environment monitoring system and an indication of the feasibility of developing an operational system in an incremental evolution.

PHASE II: (Not yet initiated)

Purpose: Define the requirements and constraints of a manned environmental monitoring mission and develop a preliminary definition of possible operations and systems.

Procedure: Utilizing the results of Phase I, and reviewing available planning on the AAP, develop the mission objectives,

system requirements, and system constraints for an environmental monitoring station. Considering such alternatives as integrated packages aboard AAP flights, separate unmanned buoys, and individual manned stations, conduct mission and operations analyses, interface analysis, and integration studies. Particular attention should be paid to the instrumentation, data handling, and communication problems associated with an operational system. Iterate these analyses as necessary to satisfy completely the objectives, requirements, and constraints defined.

Expected Results: A preliminary definition of a manned, semi-manned, and/or unmanned environmental monitoring system emphasizing system concepts and operational considerations.

PHASE III: (Not yet initiated)

Purpose: Develop a conceptual design of a manned and/or unmanned monitoring system including a developmental program.

Procedure: Utilizing the findings of Phase II, investigate the technical aspects of the design of the monitoring system. Conduct mission and operations analyses, launch system integration studies, and technical analyses to develop a conceptual design of the selected system and its evolutionary program. Include considerations of human factors, subsystem performance, system integration requirements, data dissemination, crew rotation, etc.

Expected Results: A conceptual design and operational plan of a manned and/or unmanned space environment monitoring system including the step-wise growth through developmental stages.

Phase I of this study has been completed. This report presents the results of that analysis and recommendations for the continuation into Phases II and III.

SECTION III   ANALYSIS

A.   Need for SEMOS

1.   Technology Needs   -   The initial concept for a space en-
vironment monitoring system was based on the probable requirements
of manned space flight safety. In analyzing these requirements, one is
intuitively led to consider what may be the equivalent of an operational
"space weather station". It is easy to conceive of a network analogous
to ground based atmospheric weather stations continuously sampling
many parameters and reporting data to central locations, where
synoptic charts of precipitation, wind velocity, frontal locations, pres-
sure cells, etc., can be produced for regions relatively near the surface
of the Earth. However, to carry this mental concept to a space moni-
toring system requires a thorough reevaluation.

The volume of space of possible concern is extremely large. To
provide the same proportionate coverage as the existing surface and
upper atmosphere coverage furnished by the U. S. Weather Bureau a
considerable number of sampling stations providing real-time data would
be required. The adverse economics of such a system are immediately
apparent. However, important differences exist in the operation en-
visioned for a space monitoring system. Consideration of these dif-
ferences will lead to a better understanding of the analogy.

The weather of the Earth's surface is a complex matrix of highly
dynamic occurrences. The relatively rapid rotation of the Earth which
produces significant Coriolis forces and a short diurnal cycle result
in   strong variances of the atmospheric regions. The rough topography
of the surface assists in causing the disturbances of the lower atmos-
phere. Thus, our daily weather is a worldwide system of pressure cells,
surface winds, cloud patterns, etc. Superimposed on a "nominal"
weather pattern are various localized storm occurrences of extreme
magnitude including thunderstorms, hurricanes, tornadoes, cyclones,
etc. The important aspect of this phenomenon as related to the analysis
of a SEMOS concept, is the wide spectrum of possible conditions, the
phenomenon of localized storms, and the rapidity with which they can
develop. Thus, a specific geographical location experiencing clear

and calm weather may within an hour be subjected to a severe thunder-storm. Our national weather observing system, which developed over a century of time, must necessarily resolve this time scale.

When one considers the space environment, and especially those parameters which are of interest to manned space flight safety, the time scale involved is generally greater. However, the Sun is not a constant source of energy but exhibits relatively large fluctuations. These dynamics are associated with continuous solar winds and intermittent solar flares of various intensities.* Due to the interactions with the Earth's magneto-sphere, these solar dynamics produce corresponding changes in the Earth's environment. Magnetic storms which exhibit a sudden onset and large fluctuations are the most prominent result.

When contacted during the liaison efforts of this study, Dr. Sonett of NASA/Ames felt that for the accurate prediction of the arrival of pro-tons from solar flare events, the SEMOS system should continuously monitor and be able to define the interplanetary magnetic fields which form the flux tubes which confine and direct the proton storms. Dr. Sonett believes that this field is as turbulent and rapidly varying as any wind field in micrometeorology.

Thus, it is seen that while the space environment time frame is generally greater than the surface weather, certain localized dynamic situations may exist. This problem is compensated for by the fact that orbiting systems used for monitoring the space environment necessarily maintain a high relative velocity with respect to the environment. Hence, one sampling package will provide data for numerous locations. A satellite throughout its orbit can sample many points around the Earth in a day. From a polar orbit, complete daily coverage of the Earth can occur. Thus, the weather bureau analogy, as outlined in the beginning of this Section, may be useful in discussing a SEMOS concept, although important differences exist which must be well understood.

It follows then that it is necessary to analyze the data require-ments and specific contributions of a SEMOS concept in detail to assess the need for such a system and understand in a preliminary fashion what

* In Section IV. A. of this report, the scientific aspects of the solar winds and the solar flare activity, as well as their relations to changes in the Earth's space environment are presented.

such a SEMOS system might eventually entail.

In this study a broad outlook was maintained to analyze the role of an orbital space platform in monitoring the Earth's atmospheric and space environment because it was felt that consideration of only the aspects of manned space flight safety severely limit the scope of study. To summarize this analysis, the charts presented on the following pages were produced. The study of the Earth's space and atmospheric environment was arbitrarily categorized as follows:

	(Research and Development)		Operational	(Routine Sampling and Emergency)
Scientific				
Meteorology			Telecommunications	
Oceanography			Manned Space Flight	
Earth Sciences				
Atmospheric Sciences				
Aeronomy and Astrophysics				

The following charts, Figures 2 through 8, (which at this point in the development of a SEMOS concept must be considered preliminary) present a variety of parameters and related observations. Further parameter definition and analysis of the needs is undoubtedly necessary. Estimates of some of the data requirements revealed that further literature surveys and personal contacts are necessary.

Figure 2   METEOROLOGY NEEDS

Parameters	Current Limitations	Observation Limitations (space)	Improved by Space Observations	Type	Coverage	Frequency	Resolution	Space Correlation	Real Time Data Req'd	Sensor Control Possible	Sensor Control Desirable	Role of Man Man Necessary
Wind velocity	Lower regions only		Possible	Vertical Structure	World	6 hrs*	±5 kts	Yes	Yes	x		
Front locations	Sparse network		Possible	Position, movem't	World	6 hrs*	±1/2 mi*	Yes	Yes	x		?
Jet streams			Possible	Position, velocity	World	6 hrs*	(±1/2 mi) ±5 kts	Yes	Yes	x		
Clear air turbulence	U.S. only		Possible	Position, movem't	World	6 hrs*	±1/2 mi*	Yes	Yes	x		
Rainfall distribution			Possible	Position, amount	World	6 hrs*	±	Yes	Yes	x		
Water vapor distribution	Sparse network		Yes	Am't distribution	World	6 hrs*	±1/2 mi*	Yes	Yes	x		
Forest fires	Storms		Yes	Location	U.S.	On demand	-	-	Yes			?
Air pollution	Sparse network		Yes	Location intensity	U.S.	Daily	±1/10 mi**	-	Yes	x		
Cloud type & struct.	Limited view		Yes	Vertical structure	World	6 hrs	±1/10 mi	Yes	Yes	x		
Vegetation	Sparse network		Yes	Type, location, etc	U.S.	Weekly	±1/2 mi	Yes	No	x	x	?
Water inventory		Resolution requirements	Possible	River water level	U.S.	Daily to 12 hrs	1/10 ft	Yes	No	x		
Lake & river ice	Sparse network storms		Yes	Ice coverage	U.S.	Weekly or less	200 ft	Yes	No	x		
Ozone distribution	Limited network		Yes	Vertical distri.	World	12 to 6 hrs	50 ft on coverage	Yes	Yes	x	x	
Flooding	Network flooded out		Yes	River water level	U.S.	On demand	50 ft on coverage	-	Yes			
Water pollution	Sparse network		Possible	Discharge patterns	U.S.	Daily	±1/2 mi	Yes	Yes	x		
Cloud movement	Limited view		Yes	Patterns, direction	World	Continuous	±1/10 mi	Yes	Yes	x	x	?
Orographic influences	Sparse network		Possible	Atmospheric relations	World	"	±1/10 mi	Yes	Yes	x		
Snow line, melting	Sparse network		Yes	Location	Av over 100 sq. miles	Weekly or less	500 ft of elevation	Yes	No			
Hurricanes, tornadoes, etc.	Limited view		Possible	Location, movement	World	On demand	±1/10 mi	Yes	Yes	x	x	?
Surface temperature	Sparse network		Yes	Temp. distri.	World	6 hrs	±2°	Yes	Yes	x		

*Estimated
**Source Location, Estimated

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Parameter	Current Limitations	Space Observation Limitations	Improved by Space Observations	Type	Coverage	Frequency	Resolution	Space Correlation Required	Real Time Data Req'd	Not Req'd	Not Desired	Possible	Desirable	Man Necessary
Solar Constant	Atmospheric absorption		Yes	Intensity, variations	Space	Continuous	± 2 w/m^{2}s	Yes	Yes			x		
Total density, upper Atmosphere	Infrequent sampling		Yes	(Altitude variation (constituents, etc.)	Space	Continuous	± 10 kg/m^3	Yes	Yes			x		
F-Region electrons	Infrequent sampling		Yes	Concentration vs time	Space	Continuous		Yes	Yes			x		
Positive ions	Infrequent sampling		Yes	(Identification (Diurnal variation	Space	Continuous		Yes	Yes			x		
Protons	Infrequent sampling		Yes	Concentration vs alt	Space	Continuous		Yes	Yes			x		
Trapped particles			Yes	(Particle flux (Boundaries	Van Allen	Continuous		Yes	Yes	x				
Solar Wind	Infrequent sampling		Yes	Composition, intensity	Space	Continuous		Yes	Yes			x		
Solar flare particles	Infrequent sampling		Yes	(Composition, inten. (Altitude variation	Space	On demand & trip on increase		Yes	Yes	x				
Magnetic field	Infrequent sampling		Yes	Flux, magnetosphere	Space	Continuous		Yes	Yes			x		
Cosmic Rays	Infrequent sampling	Magnetic field** shielding	Yes	(Composition, energy (Behavior in mag. fld.	Space	Continuous		Yes	Yes			x		
Micrometeorites	Sparse Network		Yes	(Size, energy, com-position, etc.	Space	Continuous		Yes	Yes			x		
Radio noise (Natural & man-made)	Atmospheric absorption		Yes	(Frequency, source (Solar contribution	Space	Continuous		Yes	Yes			x	x	
Earth albedo	Limited viewing		Yes	Intensity, variations	Earth	Continuous		Yes	No			x		
Net radiation	Limited viewing		Yes	(Emission vs geo-graphy (Radio noise (Particle density (Ionosphere (Van Allen varia.	Earth	Continuous		Yes	No			x		
Solar Flares	Atmospheric absorption		Yes	(Cosmic ray behav. (Thermal radiation (Hydromagnetic wave (Energy spectra (Intensity (Vacuum X-ray & UV	Space	Continuous		Yes	Yes	?		x		?

*Estimated

**The cosmic rays (solar and galactic) are shielded by the geomagnetic cavity only for spacecraft inside this cavity. If the spacecraft is to explore the transition region (highly desirable) and the outside of the Earth's magnetosphere, then cosmic rays are not shielded at all.

Figure 3   AERONOMY AND ASTROPHYSICS NEEDS

Figure 4 OCEANOGRAPHY NEEDS

Parameter	Current Limitations	Space Observation Limitations	Improved by Space Observations	Type	Coverage	Frequency	Resolution	Space Correlation Required	Real Time Data	Sensor Control Possible	Sensor Control Desirable	Man Necessary
Icebergs, glaciers	Sparse network		Yes	Position, size	Oceans	Daily	Size +	Yes	Yes	x		
Temp. distribution	Sparse network	Surface layers only	Yes	Temp. distribution vs depth of surface layers	Oceans	Daily*	±1/2 mi*	Yes	Yes	x		
Current patterns	No network	Surface layers only	Yes	Magnitude, direction	Oceans	Daily*	±1/2 mi*	Yes	No	x		
Evaporation	No network		Yes	Temp, dew point, wind net radiation	Oceans	12 to 6 hrs	±1/2 mi*	Yes	No	x		
Net radiation	No network		Yes	Radiation	Oceans	12 to 6 hrs	Av on 100 sq. miles	Yes	No	x		
Sea state	Sparse network	Cloud coverage	Yes	Sea state	Oceans	Daily to 12 hrs	±1/2 mi	Yes	Yes	x		
Cloud coverage	No network		Yes	Patterns, movement, vertical structures	1000 sq. mi./obs.	Daily to 12 hrs	±1/2 mi	Yes	Yes	x		
Pollution	Sparse network	Cloud coverage	Yes	Discharge patterns	River outlets	Daily	±1/2 mi*	No	Yes	x		
Erosion, silt deposit	Sparse network	Cloud coverage	Yes	Discharge patterns	River outlets	Daily	±1/2 mi	No	No	x		
Temperature to bottom	Sparse network	Depth limitations	No									
Temperature at specified depth @	Sparse network	(Resolution requirements - Surface layers only)	Yes	Synoptic	Oceans at selected positions	6 to 12 hr	±1/8 to 1/4 nm	?	Yes	x		
Salinity @	Sparse network	Sampling procedure	Yes	Synoptic	Oceans at	6 to 12 hr	±1/8 to 1/4 nm	?	Yes	x		
Dissolved gases, ions	Sparse network	"	No									
Sound velocity @	Sparse network	"	Yes	Synoptic	Selected	6 to 12 hr	±1/8 to 1/4 nm	?	Yes	x		
Optical characteristics @	Sparse network	"	Yes	Special	Selected	As needed	High	Yes	Yes	x		
Radioactivity	Sparse network	"	No									
Plankton, animal collection	Sparse network	"	No									
Bottom samples, state, etc.	Sparse network	"	No									
Bottom heat flow	Sparse network		No									

**See "Sea Effects Extended Forecasts", Undersea Technology, Vol. 6, No. 1, January 1965.

* Estimated

@ Space platform serves to collect and correlate information from dispersed buoys.

+ Special

Figure 4   OCEANOGRAPHY NEEDS

Figure 5   EARTH SCIENCES NEEDS

Parameter	Current Limitations	Space Observation Limitations	Improved by Space Observations	Type	Coverage	Frequency	Resolution	Space Correlation Necessary	Real Time Data	Possible	Desirable	Man Necessary
Volcanos			Possible	Discharge patterns	World	On demand	±1/2 mi*	-	Yes	x		
Earthquakes		Resolution requirements	Improbable	Location, faults	World	On demand	-	-	Yes		x	?
Forest inventories	Sparse network		Yes	Boundaries, type, etc.	U.S.	Weekly	±1/2 mi	Yes	No	x		
Locusts, pests, etc.	Sparse network		Possible	Location, extent	World	On demand	±500 ft*	Yes	Yes	x		
Coastal Mapping	Constantly changing		Yes	Contours, boundaries	Coasts	Weekly	±50 ft	Yes	No	x		
Chart maintenance	(Sparse network (Constantly changing		Yes	Contours, hazards, etc	Waterways	Weekly	±1 ft	Yes	No	x		
Mean low-water	(Sparse network	Resolution requirements	Possible	Land water boundary	Coasts	Daily	±1 ft	Yes	Yes	x		
Sea level	Sparse network	Resolution requirements	Possible	Elevation	Oceans	12 to 6 hrs	±1 ft	Yes	Yes	x		
Geomagnetism	Surface limited		Yes	Flux, changes, etc.	Space	12 to 6 hrs	±?	Yes	Yes	x		
Water temperature	Sparse network	Surface layers only	Yes	Temperature distribution with depth	U.S. Waterways	Daily	Av lakes ±1/2 mi rivers	Yes	Yes	x		
Radiation pattern	Sparse network		Yes	Net radiation levels	U.S.	12 to 6 hrs	Av on 100 sq. miles	Yes	Yes	x		
Water evaporation	Sparse network		Possible	Temperature, dew point, wind, net radiation	U. S.	12 to 6 hrs	Av lakes ±1/2 mi rivers	Yes	Yes	x		
Geodynamic forces		Sampling procedures	No									
Geology		Sampling procedures	Yes	Soil & mineral distri.	World	Weekly	±50 ft	Yes	No	x		
Geognosy		Sampling procedures	No									
Geodesy	Sparse network		Yes	Gravitational Flux	Space	12 to 6 hrs#	±?	Yes	Yes	x		

** See publication No. 44 in Bibliography

* Estimated

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Manned Space Flight Needs

Parameter	Current Limitations	Space Observation Limitations	Improved by Space Observations	Type	Coverage	Frequency	Real Time Data	Space Correlation Required	Role of Man — Sensor Control Possible	Role of Man — Sensor Control Desirable	Role of Man — Not Desired
Solar Constant	Sparse Network		Yes	Intensity Spectrum	Flight Regime	Continuous	Yes	Yes	x		
Total density	Sparse Network		Yes	(Constituents. (Variations	Flight Regime	Continuous	Yes	Yes	x		
Ionization	Sparse Network		Yes	(Identification (Intensity	Flight Regime	Continuous	Yes	Yes	x		?
Trapped particles	Sparse Network		Yes	Flux variations	Flight Regime	Continuous	Yes	Yes	x		?
Solar flare occurrence	Sparse		Possible		Flight Regime	On demand	Yes	-	x		?
Magnetic field	Infrequent sampling		Yes	Flux, magneto-sphere	Flight Regime	Continuous	Yes	Yes	x		
Cosmic rays	Infrequent sampling		Yes	(Composition, energy (Behavior, etc	Flight Regime	Continuous	Yes	Yes	x		
Micrometeorites	Sparse Network		Yes	Size, energy, etc.	Flight Regime	Continuous	Yes	Yes	x		
Net radiation	Limited viewing		Yes	Earth's albedo	Flight Regime	Continuous	Yes	Yes	x		x

Figure 6   MANNED SPACE FLIGHT NEEDS

Parameter	Current Limitations	Space Observation Limitations	Improved by Space Observations?	Type	Data Requirements					Role of Man		
					Coverage	Frequency	Resolution	Space Correlation Req'd.	Real Time Req'd.	Sensor Control		Man Necessary
										Possible	Desirable	
Atmospheric Noise	Atmospheric attenuation Sparse network	Background noise Receiver noise	Yes	Frequency spectrum source, location. Variations with diurnal cycle, solar cycle, etc.	Space	Continuous		Yes	Yes	x	?	
Cosmic Noise	Atmospheric attenuation Sparse network	Background noise Receiver noise	Yes	Frequency spectrum source, location. Variations with diurnal cycle, solar cycle, etc.	Space	Continuous		Yes	Yes	x		
Astronomical Sources	Atmospheric attenuation Sparse network	Background noise Receiver noise	Yes	Source location Association with astronomical bodies Frequency spectrum variations	Space	Continuous		Yes	Yes	x	?	
Ionosphere	Atmospheric attenuation Sparse network	Background noise Receiver noise	Yes	Layer definition Charge intensity Intensity contours Variations with diurnal cycle, solar cycle Propagation properties	Space	Continuous		Yes	Yes	x		

Figure 7   TELECOMMUNICATION NEEDS

Parameter	Current Limitations	Space Observation Limitations	Improved by Space Observations?	Type	Data Requirements					Role of Man		
					Coverage	Frequency	Resolution	Real Time Req'd	Space Correlation Req'd	Sensor Control Possible	Sensor Control Desireable	Man Necessary
Density	Sparse Network		Yes	(Concentration (Constituents (Variations with latitude, diurnal cycle, solar cycle	Space	Continuous		Yes	Yes	x		
Ionization	Sparse Network		Yes	(Electron concentration + ion identification (Conductivity (Variations with latitude diurnal cycle, solar cycle	Space	Continuous		Yes	Yes	x		
Penetrating Radiation	Sparse Network		Yes	(Van Allen belts (Solar flare (Cosmic (Variation with diurnal cycle, (Solar cycle, latitude, etc.	Space	Continuous		Yes	Yes	x		
Thermal Radiation	Sparse Network		Yes	(Solar constant (Albedo (Earth emission (Variations with diurnal cycle, (Solar cycle, latitude, etc.	Space	Continuous		Yes	Yes	x		
Magnetosphere	Sparse Network		Yes	(Intensity, vector (Shock front (Magnetic storms (Variation with (Solar cycle	Space	Continuous		Yes	Yes	x		

Figure 8   ATMOSPHERIC SCIENCES NEEDS

A review of the preceding charts permits an immediate statement of a number of observations:

a. From both a scientific and operational viewpoint, routine observations of the Earth's environment from space must necessarily be undertaken to achieve the improvement of our knowledge necessary to further understand the phenomena involved.

b. Space correlation of all data is almost always necessary.

c. The necessity for manned systems is not readily apparent although in only rare instances is the presence of a man not desirable. The role of man will be discussed in detail later.

d. Real time transmittal of information is important for many technologies when one is considering operational system requirements. However, if raw data is transmitted any possible communication network will be swamped as the observation system grows. This represents a major study area.

None of these statements is profound nor should they be surprising at this time; many agencies and organizations have recognized similar considerations. Of particular interest to the SEMOS concept under study herein is the work being undertaken by the Environmental Science Services Administration (ESSA) for a Manned Environmental Space Platform. A brief review of the ESSA mission and their preliminary manned station study may be appropriate here.

2. Role of ESSA - As seen on an organizational chart, Appendix A, five major functions exist within ESSA. These are as follows:

- Environmental Data Service

- Weather Bureau

- Institutes for Environmental Research

  - Earth Sciences

  - Oceanography

- Atmospheric Sciences

- Telecommunication Sciences and Aeronomy

● Coast and Geodetic Sruvey

● National Environmental Satellite Center

Thus the spectrum of scientific and operational aspects of the total Earth's environment is centered in one agency in the Department of Commerce. Realizing, as discussed above, the necessity for extending the environment monitoring function into space itself, this agency has undertaken the study of a space station to fulfill many of its missions.

.ESSA's initial study is organized as indicated in Figure 9. The Working Group No. 1 to establish the requirements has been formed and studies have been initiated.

The implications of this work upon a concept such as SEMOS are many. Primarily, the interface between ESSA and the various NASA Centers must be defined and the different roles to be played by each organization outlined. The distinction between operational and scientific exploration systems will be difficult to maintain. This is not to say that the requirements of these two systems will be the same, but that the interrelationships between the scientific community and the agencies engaged in operational activities will be extensive. The primary correlation will be in the evaluation of the phenomena involved and the development of advanced instrumentation and interpretive techniques. Any operational system cannot remain technologically stagnant but must continuously evolve in step with the scientific advancements achieved in basic knowledge, instrumentation, and other hardware developments.

Another factor contributing to this lack of distinction is the organizational structure established within ESSA. In NASA, the Office of Manned Space Flight (OMSF) is oriented toward the operational requirements and the Office of Space Sciences and Applications (OSSA) is oriented towards the scientific aspects, but the organizational distinction within ESSA is not as clear cut. The scientific (or exploratory) and operational functions exist simultaneously and are deeply interrelated. This is necessary since the inherent procedural function of ESSA is to observe, evaluate and disseminate forecasts. The forecasting function of ESSA is of direct benefit to OMSF as well as to commercial, civilian, and DOD agencies.
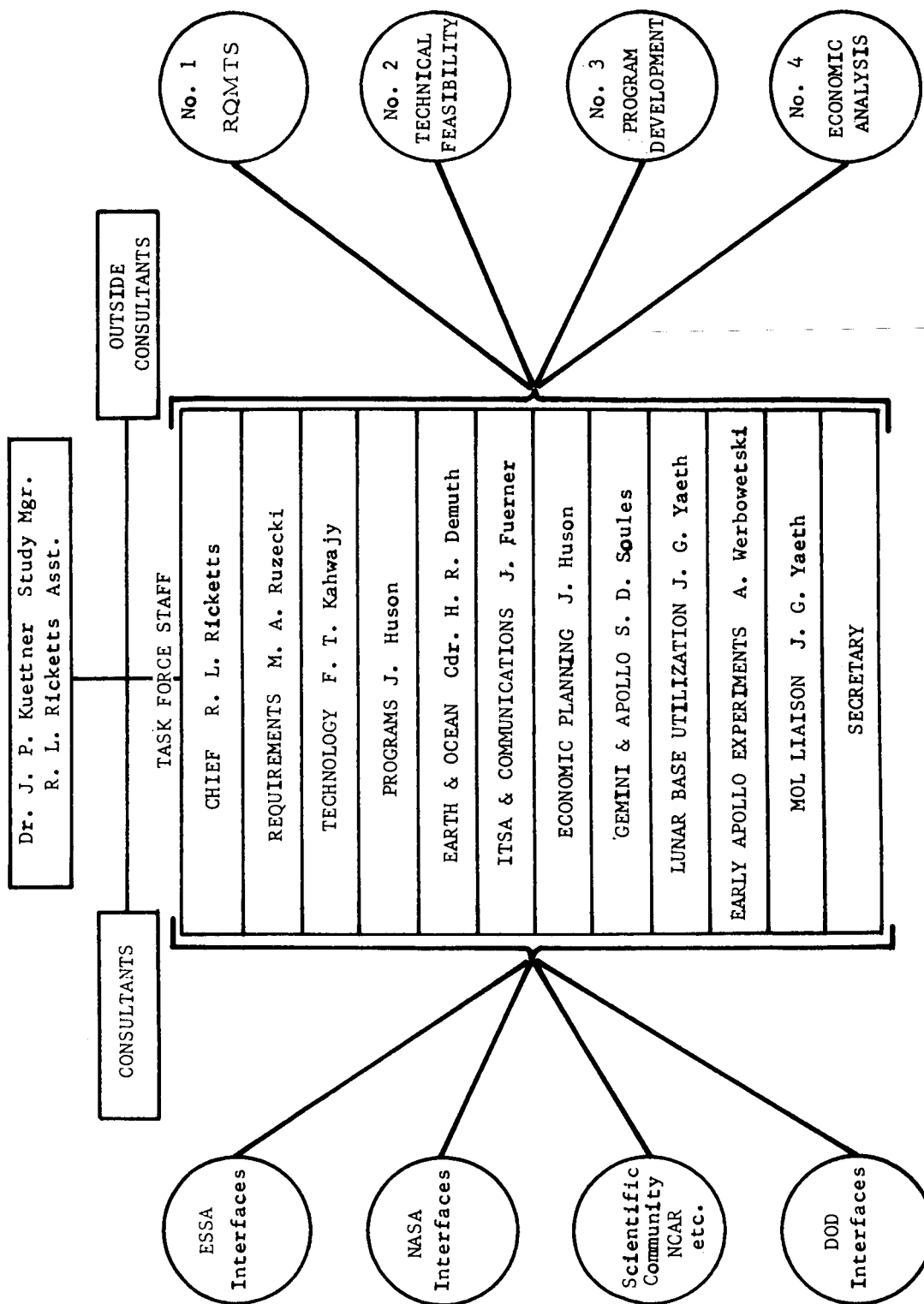
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TASK FORCE MANNED ENVIRONMENTAL SPACE PROGRAM

CONSULTANTS

OUTSIDE CONSULTANTS

Dr. J. P. Kuettner Study Mgr.
R. L. Ricketts Asst.

TASK FORCE STAFF

CHIEF   R. L. Ricketts

REQUIREMENTS M. A. Ruzecki

TECHNOLOGY F. T. Kahwajy

PROGRAMS J. Huson

EARTH & OCEAN Cdr. H. R. Demuth

ITSA & COMMUNICATIONS J. Fuerner

ECONOMIC PLANNING J. Huson

GEMINI & APOLLO S. D. Soules

LUNAR BASE UTILIZATION J. G. Yaeth

EARLY APOLLO EXPERIMENTS A. Werbowetski

MOL LIAISON J. G. Yaeth

SECRETARY

No. 1
RQMTS

No. 2
TECHNICAL
FEASIBILITY

No. 3
PROGRAM
DEVELOPMENT

No. 4
ECONOMIC
ANALYSIS

ESSA
Interfaces

NASA
Interfaces

Scientific
Community
NCAR
etc.

DOD
Interfaces

Figure 9

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This idealized integration discussion implies that the operation and utilization of a space environment monitoring system, either manned or unmanned, is the established mission of ESSA and that through active participation and development assistance, the Office of Manned Space Flight should expect to obtain the necessary operational evaluating and forecasting functions from that organization. A review of the plans and approaches being taken by the many agencies visited during the study reported herein indicates that this is, in fact, the desired evolution. Examples can be cited to illustrate this:

a.   The Manned Spacecraft Center in 1965 established a Solar Particle Alert Network (SPAN) to develop a warning system for radiation events on the Sun which could endanger astronauts on lunar missions. The evaluative and interpretive functions of this system has been transferred to ESSA's Institute for Tele-communication Sciences and Aeronomy.

b.   The TIROS operational follow-on, originally identified as TOS (TIROS operational system) and programmed by NASA-Goddard, has been converted to an ESSA system under its National Environmental Satellite Center. The satellites in the series are now designated as ESSA-I and ESSA-II, and are now beginning their operational lives.

The evolutionary development of a SEMOS concept must necessarily follow this pattern. The preliminary definition, requirements, conceptual design, and component specifications should be developed by OSSA with the assistance of OMSF and ESSA. Actual hardware, its operations, and ground support systems should also be developed by NASA agencies with ESSA playing an important role. This operation of the system would then be the responsibility of ESSA.

B.   <u>Requirements of SEMOS</u>

1.   <u>Cost and Schedules</u> - It is difficult to develop considerations of cost and scheduling for the SEMOS concept at this early date. Considerable effort in defining the system is necessary, and must include the interrelated aspects of the ground system, launch system, data reduction and dissemination, and in-orbit systems. No attempt to define these systems or to estimate the costs was made.

However, there are other economic considerations of a SEMOS concept which can be presented at this time. These revolve around the aspects of meteorology and the role of a space monitoring system in this field.

The National Research Council of the National Academy of Sciences has estimated that approximately 2.5 billion dollars a year could be saved by industrial, civilian, and agricultural organizations if the accuracy of long range weather forecasting could be improved. Table I on the following page shows the results of their 1964 study (See item No. 32 of Bibliography).

To realize these savings, accurate predictions of weather trends for two or three weeks ahead are necessary. At the present time, only predictions for up to five days have the degree of accuracy required. Thus, considerable improvement is necessary.

A further consideration is important here. The maintenance of hundreds of manned stations in remote continental and ocean areas which are presently required to gather data for long range predictions is a costly burden. If it can be shown that a satellite system could provide the necessary data for increasing forecasting accuracy and also permit the elimination of a major portion of this ground system, a strong economic argument for implementing the system could be developed. Based on these meteorological considerations above, a SEMOS concept may well be shown to pay for itself. Dr. L. Krawitz of the Astro-Electronics Division of RCA estimates that, compared to a conventional global observation system, a satellite system could save at least $150 million a year in operating costs alone. It is believed that the cost aspects of a SEMOS system would not be particularly adverse if the requirements of the meteorological sciences are kept in mind.

The correlated analysis of the schedule requirements of a SEMOS concept can also be treated only superficially at this time. Two major areas are imposing the pacing schedule restrictions. First, the technological problems associated with the development of the sensor systems, control systems, data storage and reduction systems, associated ground systems of many types, and life support systems if man is present, demand a great deal of application.

Table I   ESTIMATED SAVINGS FROM LONG RANGE
WEATHER FORECASTING

ACTIVITY	ANNUAL WORTH (Million Dollars)	ESTIMATED SAVINGS (Million Dollars)
Floods and Storms	280 (Loss)	70 to 140
New Construction	59,000	1,000
Fuels and Electric Power	40,000	500
Fruit-Vegetable Products	3,200	500
Livestock Production	9,000	450

Second, the economic capabilities of the national budget and the economic growth and development of our industrial capacity have to be considered. A large investment in resources for research, development, and fabrication must be made before an operational system can be implemented. Even though it is possible to show on paper that the investment will be returned and great savings maintained thereafter, the initial investment capability must exist. This factor will probably ultimately control the development of a SEMOS concept and thus determine its schedule.

2. <u>Instrumentation and Data Handling</u>[1] - Before detailed requirements and techniques can be developed for an operational system such as SEMOS, we must know what it is we intend to measure and have a reasonably good idea of the properties of information that will be received. There is a strong distinction between data and information, and any communications channel, no matter how broad, can be easily overfilled with data from which it is extremely difficult to extract the desired information. Considerable judgement must be exercised in the system design. The following questions must be answered in terms of each individual measurement as it is processed. How do we set a threshold and do we transmit when we exceed this threshold? Do we transmit the average background at intervals plus information on the changes in the parameter?

One must also have an idea about the statistics of the information of interest before details of overload capacity and data handling characteristics can be determined. Data management functions to decide priorities and storage is used to normalize data transmission rate in most processing systems. The processing itself is small, but storage and timing are very important. The key to a system is what must be extracted and detected. In fact, it has been quite possible in the past for a system to discard significant information from a collection of data. Few systems now in use or under design actually process data in a vehicle, they merely store it.

One of the major components of any system such as SEMOS is the memory. The GE thermoplastic memory which is currently able to store 10^5 to 10^6 bits per sq. in. per 1/10 inches thick unit is one possible solution to this problem. The peripheral equipment required for such a system will unfortunately be about ten times this volume. During the next five years the input/output equipment volume is expected to reduce by an order of magnitude while the data link capacity is expected to rise to 10^8 bits per second. It should be emphasized that experience has shown that no matter what the capacity which is furnished in a data link system, in the end the customer always manages to use the complete channel capacity.

The devices for CW[*] transponders and telemetry transmitters are of the frequency coherent type which permit phase-lock range and range rate measurement. Within the next two or three years we may expect 100 MHz[**] information rate capability. By 1971, by the use of quadraphase or other advanced techniques, we can expect equipment of similar size, mass and power consumption to be able to handle 200 to 400 MHz at 6 to 10 cycles per bit. These devices would be all solid state with, in 1967, 10 watts output at S or C band, efficiency of approximately 20 percent, 5-6 pounds mass and 60-80 cu. in. volume. By 1971, a reasonably similar equipment would be expected to deliver up to 25 watts output at S to C band and 15 watt output at X-band.

It is doubtful that more than 20 MHz will ever be needed on the up-link. If necessary, it is possible to utilize the wider bandwidth but there is currently no appropriate receiver-processor under development. We may expect mass, volume and power input to stay constant as bandwidth and data capability grows with time to match the transmitter capability.

Table II was provided by Motorola, Incorporated describing some specialized space communication systems.

Prediction of the arrival of a proton storm is not presently possible on scientific (theoretical) grounds. Once a major flare is spotted by RF, optical or X-ray detection, one can start looking for the high velocity (relativistic) protons which serve to show that:

---

[*] Continuous Wave
[**] The abbreviation Hz represents Hertz which is the equivalent of one cycle per second.

Table II SPACE COMMUNICATIONS SYSTEMS

System and Components	Current Capability	Projected Capability 1971
JPL-DSIF [2]		
Ground Transmitter Power Output	10 kw	400 kw
Ground Antennas	85' Dish	210' Dish
Ground Revr Noise Temperature	50° K	35° K
Spacecraft Antenna	3' Dish	10' Dish
Spacecraft Rcvr NF	11 db	4.5 db
NASA/MSFN [3]		
Ground Transmitter Power Output	20 kw	? (probably same as
Ground Antenna	30' to 85'	DSIF)
Ground Rcvr Noise Temperature	70°K	"
Spacecraft Transmitter Power Output	20 w	"
Spacecraft Antenna	34 db at S-band approx. 6' dia. dish	"
Spacecraft Rcvr NF	8 to 12 db	"
USAF/SGLS		
No data available		

1. Data courtesy of John Panter, Telecommunications Laboratory, WMEC, Motorola, Inc. Mr. Paul Goodwin of JPL and Dr. Robert Owens of NASA/Goddard concur.

2. For an Ultra Long Range Communications System like the DSIF, the usable bandwidth and bit rates must be calculated for each individual mission, since they are strong functions of range and system characteristics. A sample of such calculation appears in the Appendix to "The Mariner Planetary Communication System Design", G. D. Martin, Paper 8-3, Proceedings of the 1962 National Telemetering Conference, Vol. 2.

3. The MSFN is currently limited to 51.2 K bit/sec, 3.5 MHz system bandwidth, 150 KHz IF bandwidth, for 1971 operation the projected data capacity is 1 M bit/sec.

It should be emphasized that the DSIF was designed for deep space (planetary) missions, while the MSFN (which is a second generation system) was designed for use in cislunar space.

a. There is an appreciable proton output associated with that flare.

b. There is a magnetic flux linkage with the solar flare.

If the energy spectrum of the arriving protons can be plotted as a function of time, it is possible to predict the dose from a flare, and make an estimate as to the time delay involved. Some scientists contacted during this study claim that this will permit from two hours to two days of warning.

The minimal package to accomplish this would contain a pair of 2π proton detectors and a dosimeter system. One proton detector should have a brass window, its two channels will measure energies greater than 150 KEV and greater than 200 to 250 KEV. The second proton detector should have an aluminum window and would measure all protons with energies greater than 40 KEV and greater than 100 KEV. These four channels will permit a useful approximation of the proton energy spectrum. The dosimeters will record total dose, dose rate, and approximate quality of the radiation.

If greater vehicle capability is a variable, it would be useful to add the following instruments:

Unidirectional Proton Spectrometer - Telescope

Solar X-Ray Telescope

Three-Axis Magnetometer

C. Concepts of SEMOS

1. AAP Utilization - It is reasonable to expect that the Apollo Applications Program will be used to assist in the development of the SEMOS concept by conducting experiments, testing instruments, and defining the role of man. Considerable effort is currently being expended by MSFC in defining this program. The sizes and locations of areas for experiments which could be flown on AAP flights are shown on the two following charts, Figures 10 and 11. These data are only approximate and, depending on mission parameters, can vary considerably. It can be seen that a variety of
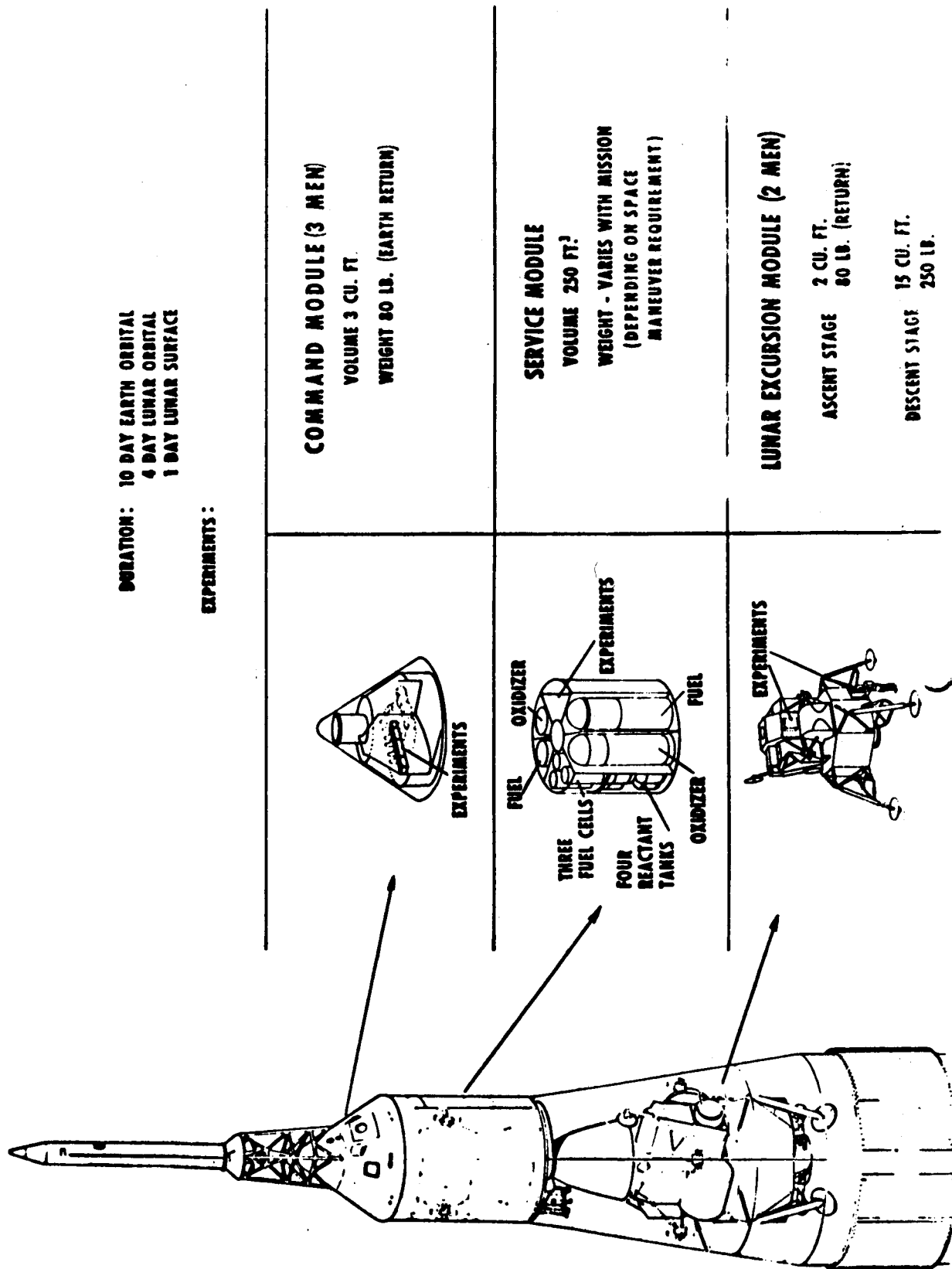
PRESENT APOLLO CAPABILITY

DURATION: 10 DAY EARTH ORBITAL
4 DAY LUNAR ORBITAL
1 DAY LUNAR SURFACE

EXPERIMENTS :

COMMAND MODULE (3 MEN)

VOLUME 3 CU. FT.

WEIGHT 80 LB. (EARTH RETURN)

SERVICE MODULE

VOLUME 250 FT?

WEIGHT - VARIES WITH MISSION
(DEPENDING ON SPACE
MANEUVER REQUIREMENT)

LUNAR EXCURSION MODULE (2 MEN)

ASCENT STAGE   2 CU. FT.
80 LB. (RETURN)

DESCENT STAGE   15 CU. FT.
250 LB.

EXPERIMENTS

FUEL

OXIDIZER

EXPERIMENTS

FUEL

THREE
FUEL CELLS

FOUR
REACTANT
TANKS

OXIDIZER

EXPERIMENTS

Figure 10

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EXTENDED APOLLO CAPABILITY FOR EXPERIMENT SUPPORT

DURATION: EARTH ORBIT: 4 TO 6 WEEKS (POSSIBLY TO 3 MONTHS)

LUNAR ORBIT: UP TO 1 MONTH

LUNAR SURFACE: UP TO 2 WEEKS

EXPERIMENT VOLUME

EXPERIMENT WEIGHT

COMMAND MODULE

EXPERIMENT VOLUME	EXPERIMENT WEIGHT
EQUIPMENT BAYS: 120 cu.ft. FREE VOLUME: 90 cu.ft.	WITH 3-MAN CREW: UP TO 250 LBS RETURN WEIGHT WITH 2-MAN CREW: UP TO 500 LBS RETURN WEIGHT

SERVICE MODULE

210 cu.ft. IN SECTOR 1 (ADDITIONAL VOLUME IN OTHER SECTORS FOR EXTENDED EARTH ORBIT MISSIONS)	VARIES WITH MISSION REQUIREMENTS FOR PROPELLANT AND EXPENDABLES; e.g., FOR LUNAR SURVEY MISSIONS, CAMERA SYSTEMS WEIGHING ~1500 LBS COULD BE INSTALLED IN SECTOR 1

LUNAR EXCURSION MODULE (LEM)

ASCENT STAGE: ~220 cu.ft. LAB SPACE FOR EXPERIMENTS AND OPERATIONS DESCENT STAGE: ~15 cu. ft. INTERNAL (ADDITIONAL EXTERNAL VOLUME WITHIN ADAPTER)	VARIES WITH MISSION REQUIREMENTS

LEM ADAPTER

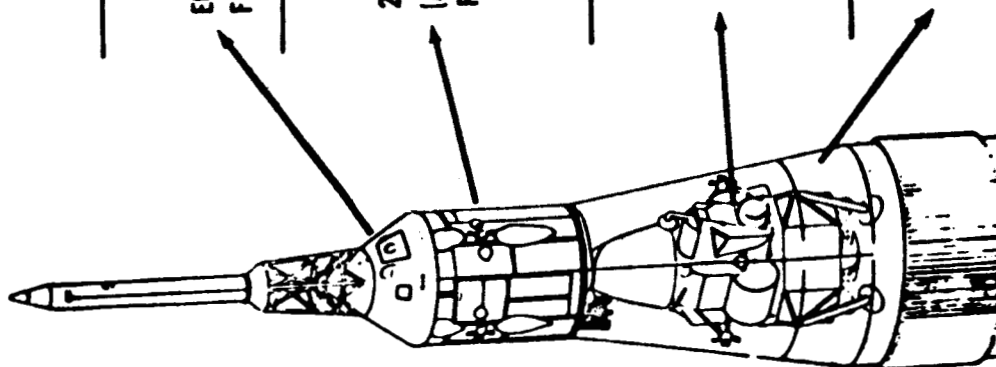|	
UP TO 6000 cu. ft. WITHOUT LEM	VARIES WITH MISSION REQUIREMENTS FOR SATURN I MISSIONS IN EARTH ORBIT, MORE THAN 30,000 LBS POSSIBLE IF LEM IS OMITTED

Figure 11
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volume and mass capacities are available which in general exceed the preliminary requirements discussed in Section III. B of this report. It is not necessary to present in detail the present planning, but certain aspects of the program are of interest.

First, and perhaps most important, the Earth-orbital missions of AAP may show whether man is necessary, useful, or ineffective as a contributor to space environment monitoring. In addition to defining his role as an experimenter or maintenance man, the long duration missions under consideration (up to 135 days with rendezvous), will indicate the psychological and physiological deterioration in his capabilities and hopefully establish the requirements for crew size, rotation periods, space cabin requirements, etc. , of concern in designing a manned SEMOS system.

Secondly, the specific mode of operation currently being defined for AAP limits and directs the extent to which it can be applied to SEMOS. In general, the concept is one of flying experiments in scientific, applications, and research and technology areas. These experiments are to be flown after an evolutionary process of submittal, evaluation, selection, and development. Because this is a time consuming process it must be applied early to space monitoring experiments if the flight schedules being proposed by NASA are to be utilized in developing SEMOS hardware. If these schedules are met, it is conceivable that further development of the Apollo Applications Program could actually be centered around the development of a space monitoring system.

The establishment of a World Weather Watch program, under the auspices of the United Nations (specifically, the World Meteorological Organization) to which the United States contributes substantially has developed great interest in meteorological satellites. ESSA has undertaken the responsibility of directing America's role in this system and NASA's Goddard Space Flight Center has completed the development and launch of the satellite systems. The success of these spacecraft and the rapid expansion of the weather observation program is evoking considerable interest around the world. Continuous and extensive growth can be expected and as the benefits of the effort are realized, the idea of observing, analyzing, and forecasting the weather may well develop as an international goal of the peaceful uses of space. As ESSA gains in stature and operational proficiency, long range weather forecasting will certainly become a reality in this nation.

To accomplish the missions of ESSA, they have embarked on programs leading to the requirements for more sophisticated unmanned satellite systems and on the study of future manned orbital stations. The extension of these efforts to include the space environment is certainly logical, especially when it is realized that extensive interrelations between the space environment and atmospheric regions are of interest to meteorologists. Thus, the possible development of a manned station for ESSA may well be compatible with the evolution of the AAP concept. A permanent orbital station, based either on extended Apollo capabilities or the precursor of a MORL-type system could easily be oriented toward a joint space/meteorological monitoring system.

It was not within the scope of this study to develop conceptual designs of the SEMOS hardware. However, based on the results of this brief analysis, it is possible to obtain a very preliminary idea of possible AAP packages.

Of considerable interest in a SEMOS study would be the capabilities of the service module "pallet". While the entire pallet is very large and would represent a major satellite system, the same volume on the service module may be used for a number of SEMOS buoys. These buoys could be ejected in the Saturn parking orbit or, on lunar flights, ejected in cis-lunar space. On-board propulsion systems would be required to circularize or otherwise modify the buoy orbits from the translunar trajectory path of the Apollo. The use of a propulsion system implies the requirement of a guidance system. At this time it is believed relatively crude systems would suffice.

Based on this brief outlook, a concept illustrated in Figure 12 was developed. A conceptual buoy configuration is shown in Figure 13. A brief description of the subsystems of these buoys as presently conceived for a SEMOS concept is presented below. It should be noted that these concepts are preliminary at this time and further detail analysis is required.

Configuration

Rectangular box 23" x 23" x 24"

Solar paddle angles can be varied to provide for solar orientation or for random orientation.

SEMOS Buoys
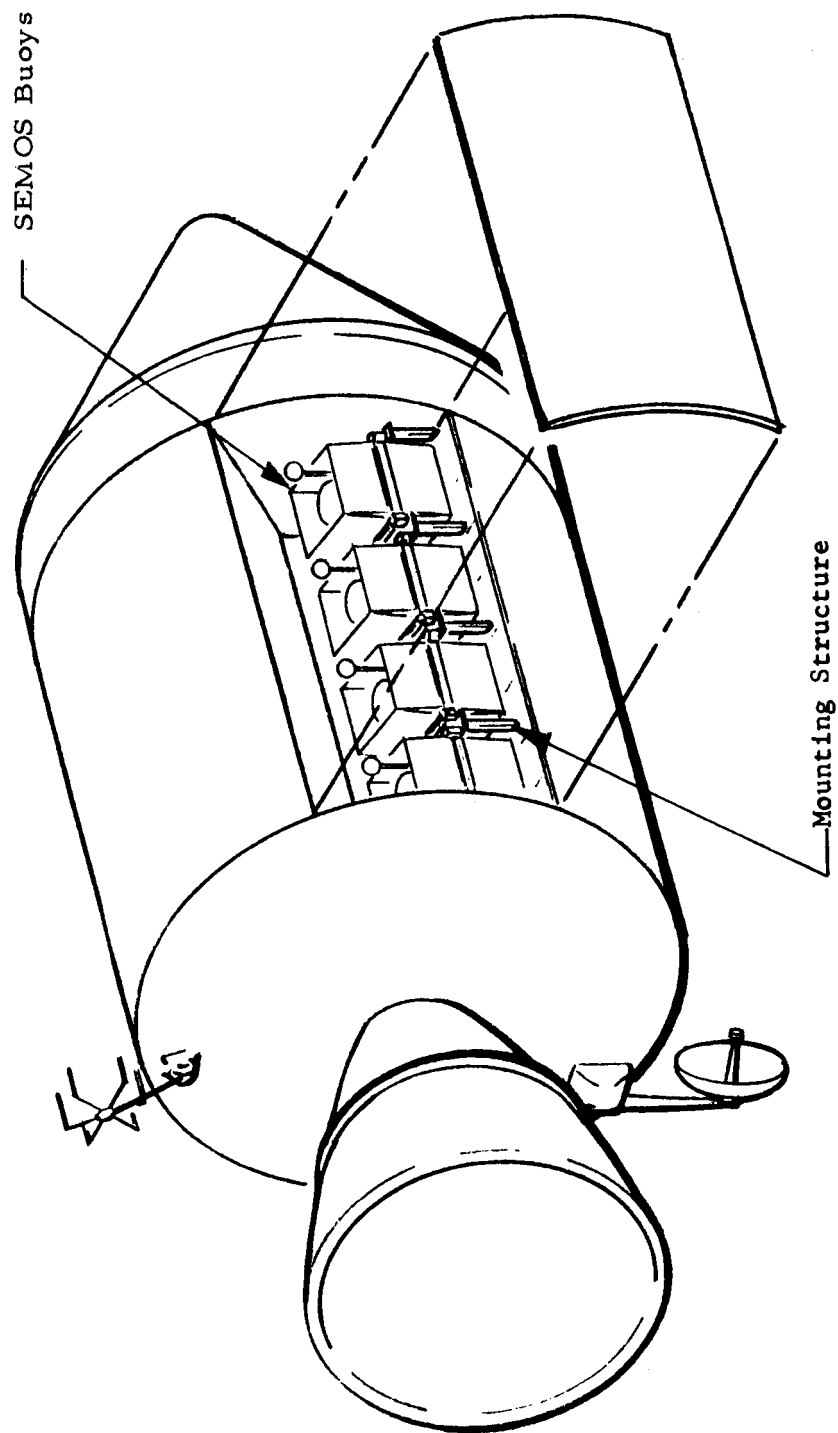
Mounting Structure

Figure 12   SEMOS BUOYS IN AAP PALLET AREA
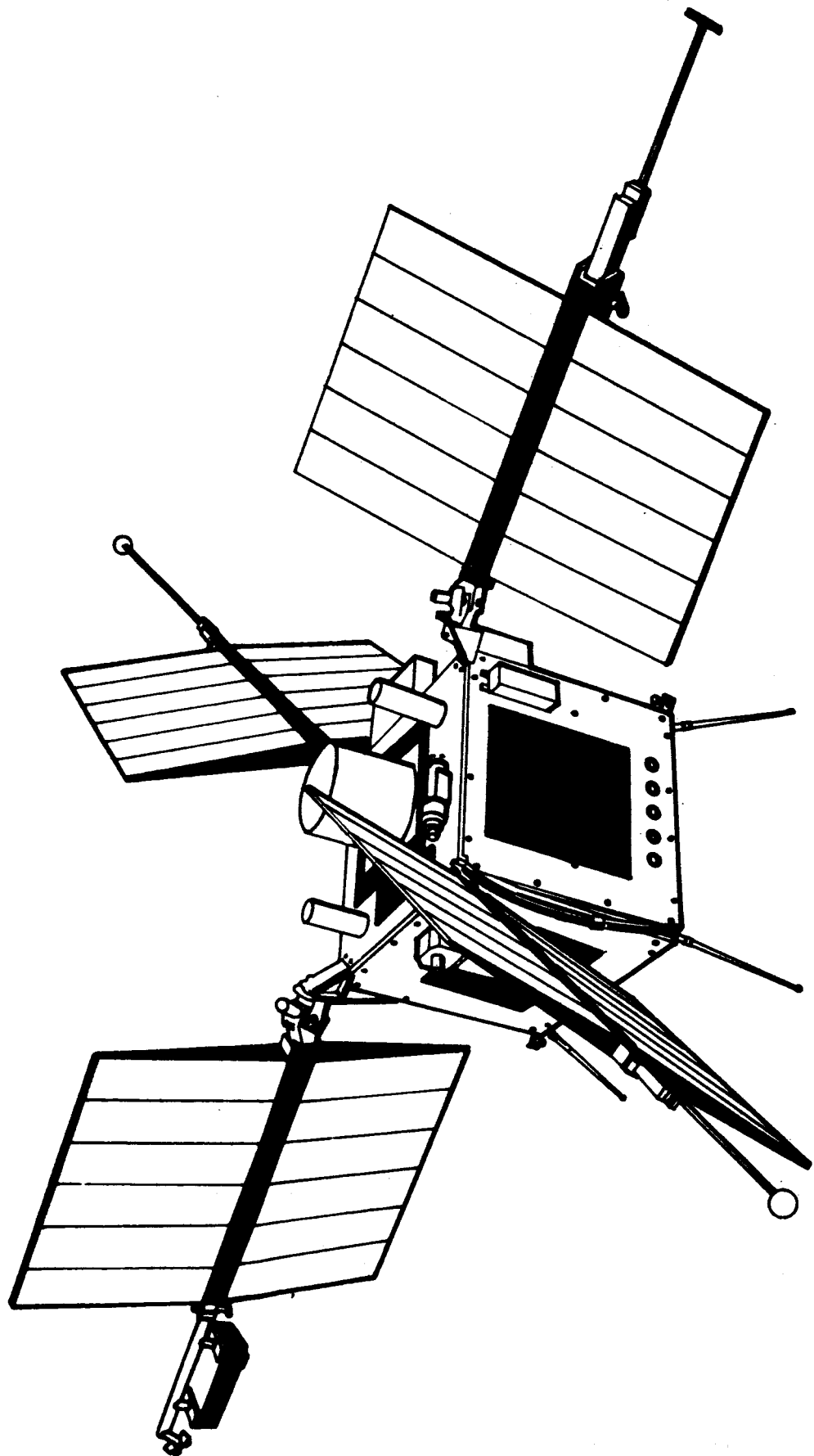
POSSIBLE SEMOS BUOY CONCEPT

Figure 13
-35-

Tested to severe launch environment

Capable of being spin stabilized

Instrument Mounting:

Entire exterior of box structure, ends of solar paddles and some interior space is available for scientific instrumentation.

Structure can accommodate nearly all magnetic requirements

Booms may be provided as required

Power Supply

Solar array battery supplemented system capable of the following approximate power levels:

Power Level	Shadow Time	Duty Cycle
40 Watts	33%	50%
72 Watts	0%	25%

Weight:

Spacecraft without experiments = 250 pounds

Average total payload weights flown to date = 100 to 200 pounds but, depending on structural limitations, considerably more payload can be accommodated.

Stabilization and Orientation:

Three axes gravity gradient system represents more economic and reliable system for SEMOS buoys.

Temperature Control:

Passive control using surface coatings and finishes plus fixed shields and blankets

Basic cubic structure average temp. $70^\circ F \pm 20^\circ F$.

All other equipment external to structure $70^\circ F \pm 30^\circ F$.

Control verified by space chamber tests and actual flight test data.

Data Handling:

Hybrid system PCM and PAM, no storage, real time operation only; solid state commutator, 8 bit words, IRIG standards.

This subsystem can be modified for a specific spacecraft application to satisfy experimenter needs.

Propulsion System:

If maneuverability is required, it is believed at this time that a bi-propellant N_2O_4/N_2H_4-UDMH system using the MSFC "universal" C-1 engine would be appropriate. This engine was designed for multiple application and has a nominal thrust of 100 lbf. Based on very preliminary analysis, a ΔV capability of approximately 1500 feet per second would satisfy most maneuvering requirements conceived for SEMOS buoys. Total propulsion system weight of about 70 pounds may be expected.

Instrumentation:

The following experimental instrumentation has been designed for an existing series of satellites.

Directional Particle Detector
Faraday Cup
Cerenkov Detector
VLF Receiver
Magnetometer
Electrostatic Analyzer
Tissue Equivalent Phantom
Solar Aspect Indicator
de/dx - E Telescope
Solar x-Ray and Lyman-Alpha Flux and Spectral
  Distribution

All Sky Lyman-Alpha
Low and High Energy Faraday Cup
Omnidirectional Spectrometer
Low Energy Magnetic Electron Spectrometer
Very Low Frequency EM Radiation Detector
Electron Fluxes and Pitch Angles
Primary and Trapped Cosmic Radiation Detector
Plasma Probe
Standing Wave Impedance Probe
Ion Density, Electron Density and Electron Energy
 Distribution Detectors

In addition to the space available in the pallet area of the Apollo service module, it should be noted that considerable unused volume exists in the LEM adapter region. SEMOS buoys could also be mounted in this area on AAP flights and ejected into orbits. Further study is required to assess the integration problems of this concept. Structural integrity of the LEM adapter shrouds, ejection scheme, and system interfaces are of primary concern.

2.   Satellite Systems - Starting from the data gathered by the AAP packages, and from experience obtained in operational instrumentation, data handling and processing, communication, and dissemination systems it is conceived that SEMOS buoys could be placed in suitable orbits around the Earth at various altitudes and inclinations including polar orbits. To minimize the number of ground stations required, these buoys could be launched into repetitive (phased array) orbits. Depending on the altitude of the satellites, the buoys would pass over any given ground station periodically. Figure 14 shows the altitude of circular orbits necessary to achieve this repetitive system. It can be seen that orbit inclination has a minor effect on the selection of the altitude.

An alternate concept would be to launch the buoys into orbits selected specifically on the basis of the environmental parameters to be measured. The altitude of each satellite would be chosen so as to carry it through a particular region of space. Either circular or elliptical orbits could be utilized. Thus, depending on the frequency of data required, space coverage necessary, and expected fluctuations in the environmental parameter under consideration in this concept, the SEMOS space

LEM ADAPTER REGION

VIEW A-A

POSSIBLE LOCATIONS FOR SEMOS BUOYS(TYP)

LEM EXTRACTION ENVELOPE
IF LEM FLOWN, AVAILABLE
FOR SEMOS BUOYS IF NO LEM

LEM SHROUDS OPEN (TYP)

CABLE RACK ENVELOPE

A ↓   IU

SIV-B STAGE EQUIPMENT ENVELOPE

IU EQUIP. ENVELOPE

A

SIV-B STAGE
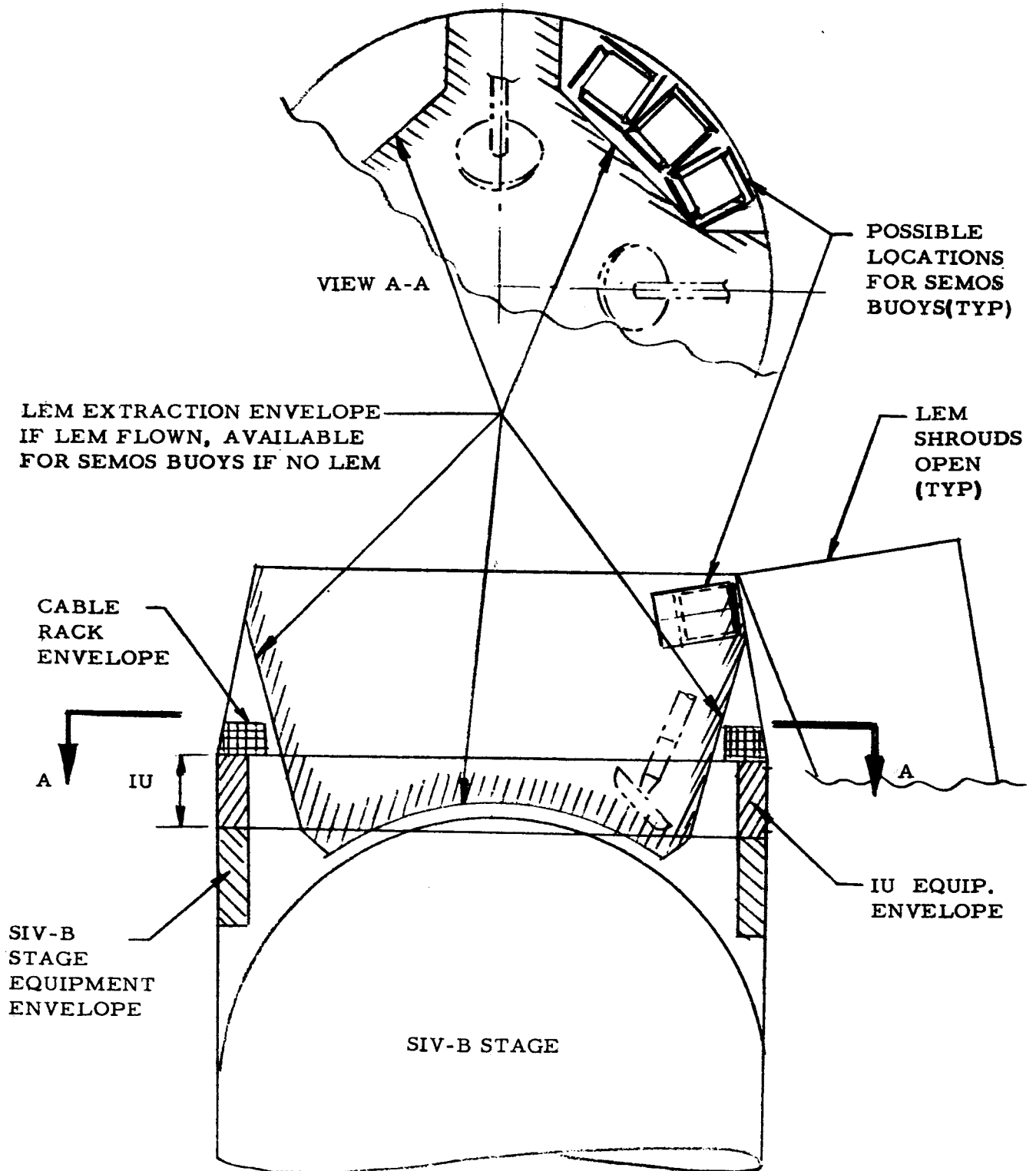
FIGURE 14

SEMOS SPACE BUOYS
– Phased Array –

• Ground Station: AMR, $\phi = 28.5°$
• Circular Orbits
• Corrected for Oblateness

i = 90°
i = 30°

Orbital Altitude (n. mi)

Buoy Revolutions (per day)

Daily Passage
Every 2nd Day
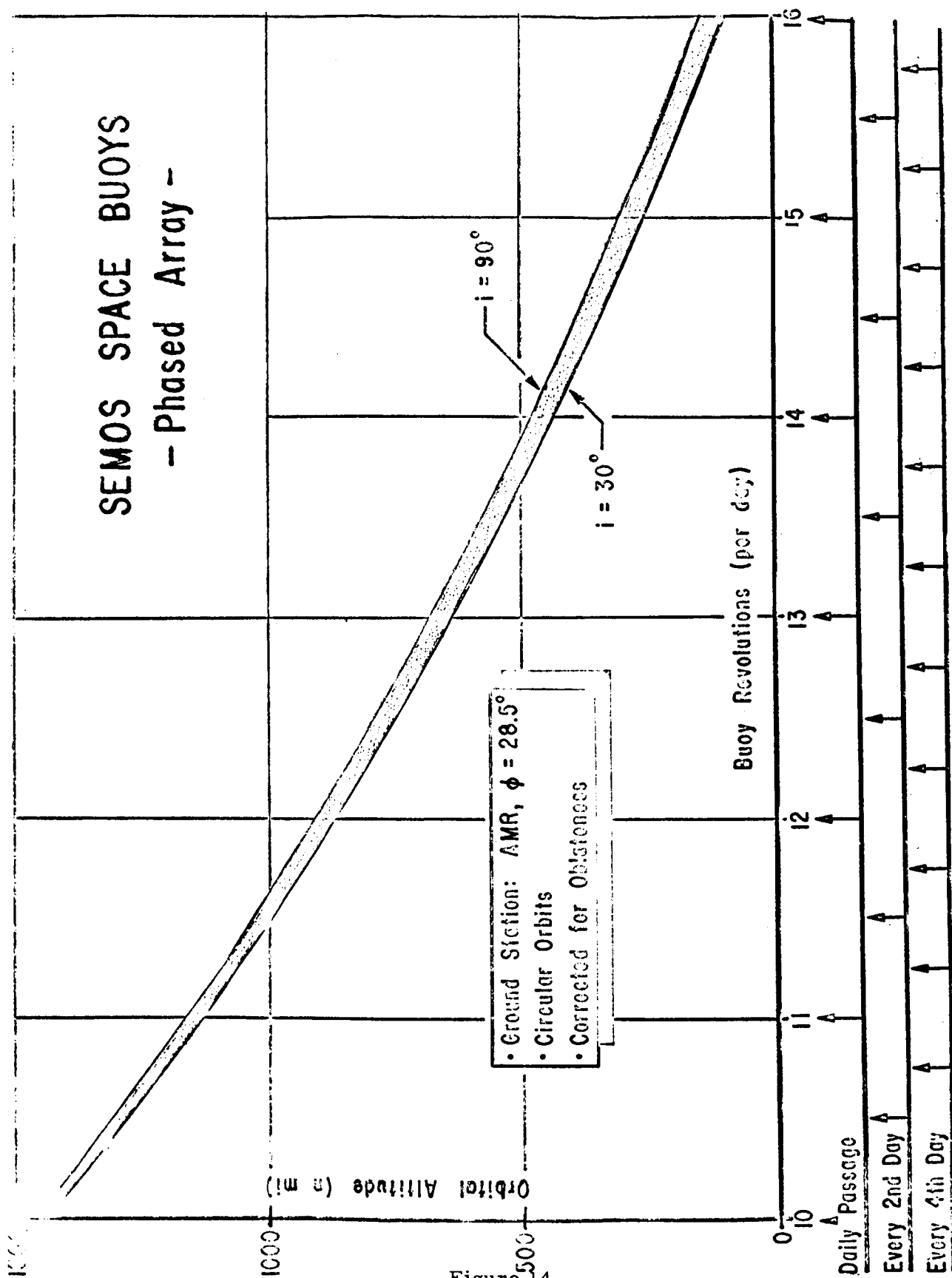Every 4th Day

Figure 14
-40-

independent of the locations of the ground stations.

To fulfill the data transmission requirements of such a system, two or more unmanned satellites equipped with onboard computers, data handling and processing facilities, and powerful antennas, could be placed in synchronous orbits. These satellites will be the focii of communication of signals from the swarm of satellite buoys monitoring the near-Earth environments. The signals collected will then be processed from raw data by onboard computers. Some filtering and logical gateing techniques will be needed to group the same type of data and to store it for processing and for communication to earth stations.

A secondary application of these unmanned focal satellites could be to observe the solar flares and to carry out astronomical observations. A conceptual arrangement of this system of satellites is shown in Figure 15.

It should be noted that a similar system has been studied by RCA to meet the communication requirements of the world weather watch system being developed for ESSA. Further analysis is needed to determine the appropriateness to a SEMOS concept.

Also of interest is the role which may eventually be played by COMSAT. Early Apollo data links are to be provided by that Corporation and, if successful, may offer usable capabilities to a SEMOS concept.

3. <u>Manned Space Stations</u> - It was originally conceived that the third phase of the SEMOS study would center on preliminary design considerations of permanent manned stations in geostationary orbit. The general opinions of several scientists contacted during SEMOS liaison, was that the level of radiation in the space region containing a synchronous orbit appears to be high enough to require very heavy shielding of the space station. Furthermore, the solar flare particles could not be easily stopped from reaching the vehicle at synchronous orbit altitude. However, a permanent manned orbiting laboratory for SEMOS may be feasible in near-Earth orbits. For these orbits, a computer program has* been developed to determine the flux and composite spectrum at various points along the orbits, and to calculate the energy spectrum

*See Reference 65 in Bibliography.

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CONCEPTUAL DESIGN ~ SEMOS SATELLITE SYSTEM

WEST COAST RECEIVING STATION

EAST COAST RECEIVING STATION

SEMOS BUOYS
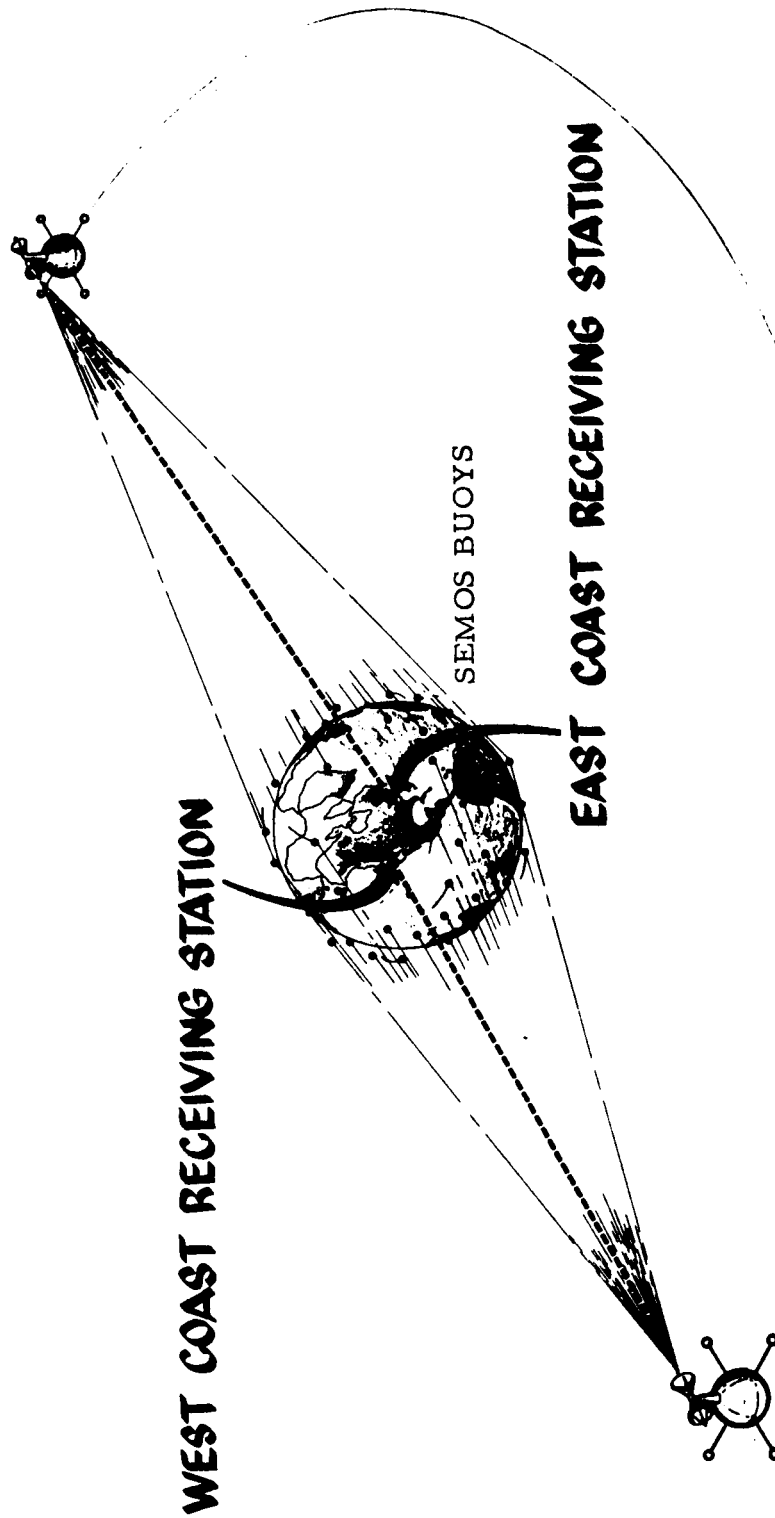
NORTHROP SPACE LABORATORIES

Figure 16

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and dose within any vehicle configuration. It is estimated that
for orbits up to about 125 nautical miles, a manned vehicle will
require very little shielding. However, the shielding requirements
rise rapidly above this altitude.

Shielding against solar cosmic rays, Van Allen Belt pro-
tons, and particles in the artificial radiation belt are necessary
either inside or outside the earth's magnetosphere because the
high energy involved for these particles. On the other hand, the
solar wind plasma is shielded naturally by the Earth's magnet-
osphere so that shielding is not necessary provided the orbits
of the spacecraft are inside the geomagnetic cavity.

It must be remembered that as an operational observer,
i. e., a living sensor, man is severely limited. His innate
senses do not respond to the spectrum of electromagnetic radiation
of concern and other parameters such as density, ionization,
magnetic flux, atomic constituents, etc., cannot be sensed at
all. Although these sensing functions are better accomplished
by nonhuman devices, man has unusually superior capabilities
in perceiving and interpreting sensory information. Thus, man
can discriminate signals, identify patterns, understand incomplete
data, select his perceptions, etc. In general, he does not need
preprogramming, he is flexible and deals with unforeseen situations,
he can exercise judgement, and he can respond to a variety or
combination of signals. On the other hand, data processing devices
are superior in terms of data storage and recall, numerical com-
putations, routine decisions, response time, etc.

Another unique feature of man is his behaviorial characteristics.
Two such factors which are necessarily of considerable interest in
studying a SEMOS concept are listed below:

    a.   Learning - machines can store or record items
        of information to a much larger extent and more
        accurately than man, but learning is an innate human
        quality. This is accomplished by practicing a skill

over and over, by trial and error, or by instruction.

b. Motivation - man's capabilities vary depending
    on many factors. Fatigue, boredom, and anxiety are
    primary impairments of human performance which
    machines never exhibit.

These two factors represent a trade-off in the development of a
man-machine system. In general, such systems usually represent a
compromise wherein the man and machine are not competitors but rather
complement each other.

The inclusion of man in a system design imposes a number of
requirements which must be studied in detail in the context of the previous
discussion. Specifically, the life support systems necessary to sustain
man are heavy, sophisticated, and costly. Also, man's presence may
introduce dynamic disturbances which may in many cases, be undesirable.
In situations where precise sensor pointing is necessary, the stability
and control system requirements may become extraordinarily severe in
a manned station. With the advent of the large SATURN V class of boosters
and the requirements conceived for an operational system, it is not felt at
this time that these factors detract from a SEMOS concept. Abnormally
precise sensor pointing is not necessary for the operational system being
considered herein.

The most significant contributions which man can make in an
operational system such as SEMOS are listed below. These functions
may occur through his permanent presence in a large manned laboratory
or through occasional visits to unmanned labs or buoys.

a. to act as an experimenter by operating instruments, develop-
    ing operational techniques, testing advanced instrumentation,
    selecting sensors, setting instruments, and initiating experi-
    ments,

b. to conduct specialized non-routine types of observations,
    account for unexpected results and phenomenon, and ob-
    serve unique activities (storm modification attempts, space
    vehicle reentries, etc.),

c. to maintain, service, repair, and replace instruments, equip-
    ment, etc., either on a routine or on an emergency basis,

d.   to calibrate and adjust instruments, calibrate new instruments, compare advanced instrumentation operation and results, and certify standard instrumentation.

e.   to assemble experiments, erect antennas, deploy booms or external experiments, jettison packages of instruments, etc., either from inside the laboratory or with extravehicular excursions,

f.   to collect data, reduce or edit data, interpret results, store or return recording cassettes, and activate data recovery capsules.

In these respects, man cannot be excelled by machines or robots in intuitive reasoning, trouble-shooting, decision making, and unprogrammed manual dexterity. As a space monitoring system increases in complexity, reliability of operation must be maintained despite ever increasing sophistication. Beyond a certain level of complexity, the use of man for the functions listed above becomes almost mandatory. This has been demonstrated in many Earth-bound situations. The presence of a man who can make adjustments and procedural decisions through his own intelligence as the monitoring of the space environment continues, may therefore represent a considerable saving of time and money.

The use of man in space must, however, not escape the ultimate cost effectiveness test if the operational system is to be developed on a sound economic basis. The lifetime in orbit is shorter for the near-Earth orbiting station, and will affect the evaluation of man's contribution onboard SEMOS vehicles. Against the short lifetime of the manned station, is the three to five year duration of unmanned satellites. Hence, the cost of having a manned station in the SEMOS system will have to be carefully examined, and unless man's contribution is particularly unique for a given application, or he can serve multipurpose uses not practical in the unmanned satellite, unmanned vehicles will have to be preferred.

SECTION IV   ENVIRONMENTAL REVIEW

A.   ENVIRONMENTAL DESCRIPTION

The study of the Earth's space environments by space orbiting vehicles may commence with that part of the upper atmosphere which may be considered as above the region accessible by balloons (25 km). The Earth's space environments of interest for the present study consists of the upper atmosphere extending into cislunar space. The present discussion will be primarily concerned with the region of space in which the earth orbiting stations will operate. These regions may be defined as follows:

1.   Atmosphere   -   This region consists of:

   a.   Troposphere   (10 km over the poles)
                         (16 km over the equator)

   b.   Stratosphere   (10 - 16 km)

   c.   Mesophere   (16 - 80 km)

   d.   Thermosphere   (80 - 600 km)

   e.   Exosphere   (600 - 5000 km)

The constituents of the atmosphere vary with altitude as well as with solar cycle and latitude. Only limited data exists regarding the detailed concentrations of the constituents and some uncertainty has been expressed in the identification of the constituents themselves.

Because the sun heats the atmosphere nonuniformly, the physical properties of these regions vary in space and time. Complicated pressure and temperature relations exist which vary diurnally and with the solar cycle. Pressure gradients may occur horizontally as well as vertically creating a tendency for horizontal atmospheric movement. Because of the rotation of the Earth, there is also a Coriolis force deflecting these movements.

2. Ionosphere - The radiation from the sun contains sufficient energy at short (ultraviolet and soft x-ray) wavelengths to cause photo-dissociation of O_2 and N_2 and appreciable photo-ionization of O_2 in the upper atmosphere. This region is known as the ionosphere and consists of several merging partially-ionized layers created or intensified during the sunlit hours. The recombination of ions and electrons proceeds slowly enough such that fairly high concentrations of electrons persist through the night.

The presence of electrons and ions in the ionosphere makes this atmospheric region electrically conducting. The conductivity depends on many factors including the ion mass, electron density, and ion and electron cyclotron frequency.

The presence of the Earth's magnetic field restricts the motion of the charged particles across the magnetic field lines resulting in the conductivity of the ionosphere being anisotropic. Diurnal and solar cycle variations in electron concentration produce correlated conductivity variations. The resultant conductivity have been defined for use in various different physical situations which occur. These are as follows:

a. Specific conductivity (parallel to magnetic field or in the absence of a magnetic field) = σ_0

b. Pederson conductivity (perpendicular to magnetic field) = σ_1

c. Hall conductivity = σ_2

d. Cowling conductivity = $\sigma_3 = \sigma_1 + \dfrac{\sigma_2^2}{\sigma_1}$

3. Protonosphere - At approximately 1000 km to 1300 km altitude, the predominant ionic constituent changes from atomic oxygen to protons. The protons are formed by charge exchange between neutral hydrogen and atomic oxygen, rather than by direct photo-ionization. This charge-exchange process ($O^+ + H \rightarrow H^+ + O$, Johnson 1960) can take place down to a critical level of near 800 km but the protons obey a diffusive distribution law that depends on the concentrations and masses of the other ions present. Effectively, the protons "float" on the heavier ions.

The total number of protons in the protonosphere is fairly constant both through day and night although variations with season or solar cycle occur.

The protonosphere is thought to be the medium for the propagation of whistlers. These low-frequency signals are apparently generated by lightening strokes and follow paths along the Earth's magnetic field lines from one hemisphere to another.

4.   Solar Radiations   -   The solar spectrum extends from the long radio waves down to hard x-rays and γ-rays. The visible 4000 - 7000 Å region of the solar spectrum corresponds approximately to black body radiation at $6000^\circ K$ and originates in the base of the photosphere. At very short wavelengths, we are concerned with emission from the chromosphere and the corona ($10^6 K$). The radiation from the chromosphere consists almost entirely of emission lines. The predominate emission lines are those of hydrogen and helium, the strongest being the hydrogen Lyman-α line at 1216 Å. At wavelengths below about 1000 Å, we are concerned primarily with emission from the corona. From 10 Å to 1000 Å the solar spectrum is roughly that of a black body at $0.5 \times 10^6 K$ corresponding to the lower part of the corona. While over a great deal of the solar spectrum there is little variation of emission during the solar cycle, there are important variations at x-ray wavelengths. In the 44 Å to 60 Å band there was a sevenfold increase in intensity between the last sunspot minimum and the last sunspot maximum, and from 8 Å to 20 Å the increase was by a factor of at least 45, and in the 2 Å to 8 Å band the increase involved a factor of a few hundred. Increases in radiation from the sun at the radio end of the spectrum show correlation with increases at the x-ray end of the spectrum.

5.   Solar Winds and Solar Cosmic Rays   -   Both solar winds and solar cosmic rays are streams of plasma flowing approximately radially outward from the sun.

The fact that light from the sun and the stars travels though the interplanetary space without apparent effect, and planets and comets experience no apparent drag indicate that the contents of the interplanetary space, if any, must be of extremely low density and great transparency. Nevertheless, a number of phenomena were discovered which were quite sensitive to the composition of the interplanetary medium even before the advent of modern instrumented satellite. For example, the zodiacal light is the result of scattering of sunlight from free electrons (Thomson Scattering) and relatively large dust particles (Mie Scattering) present in the interplanetary space. Dust is ejected from comets as the comets pass through the inner solar system. In general, the phenomena of dim light from space (such as polar aurora, zodiacal light, airglow, starlight, geigenschein) indicate that the

interplanetary medium consists of dust particles, free electrons and protons (10 ∿100 Kev) as well as charged and neutral atoms. In addition, the occurrence of geomagnetic storms, accompanied by Forbush decreases in the galactic cosmic-ray flux; and correlated in time with the appearance of large chromospheric flares on the sun, is best interpreted as resulting from the passage of a solar plasma of particularly high energy density.

Solar cosmic rays are energetic particles, (such as protons, electrons, and heavier nuclei in the Mev∿Bev range) that are emitted by the active regions of the solar surface during a solar flare. In addition to energetic particle emission there are also electromagnetic radiations, extending from the ultraviolet and x-ray wavelength to the long radio waves, associated with solar flares as mentioned before. (Part 4)   The detailed mechanism responsible for the intermittent solar cosmic ray emission as well as the origin of the continuous emission of the solar wind are still not understood. However, for purposes of prediction and shielding, methods of statistical correlation of certain solar index with radio noise are available.

6.   Corpuscular Radiation   -   Because the existence of these environmental phenomena were not known due to the atmospheric shielding and shielding from the magnetosphere of the Earth until the advent of satellite systems, considerable gaps in the knowledge of penetrating radiations exist. Therefore, the discussions presented below, which briefly summarize the available information give a far from complete picture of the situation.

a.   Van Allen radiation consists of high energy charged particles (both electrons and protons) trapped in the Earth's magnetic field. These particles execute a complex motion within certain constraining lines of the approximately dipolar magnetic field. Two definable components of Van Allen radiation exist, namely, an inner and outer Van Allen belt. The proton belt appears to be centered at about 10×10^3 km from the Earth's magnetic axis and the electron belt apparently extends through the region occupied by the proton belt. Typical values of important parameters are shown in Table III.

b.   Auroral radiation occurring in certain restricted zones of the Earth's environment contains both

Table III   VAN ALLEN RADIATION BELTS

A.   <u>SOME SAMPLE ABSOLUTE INTENSITIES</u>

    1.   In heart of the inner zone ($L \sim 1.4$, $B = 0.12$)

        Protons ($E > 30$ Mev), $J_o \sim 3 \times 10^4/cm^2$-sec

        Electrons ($E > 600$ Kev), $J_o \sim 2 \times 10^6 cm^2$-sec

        Electrons ($E > 40$ Kev), $J_o \sim 10^8/cm^2$-sec

    2.   In heart of the outer zone ($L \sim 3.5$)

        Electrons ($E > 40$ Kev), $J_o \sim 10^7/cm^2$-sec

        Electrons ($1.5 < E < 5$ Mev), $J \sim 10^4/cm^2/sec$

        Protons ($0.1 < E < 5$ Mev), $J_o \sim 10^8/cm^2$-sec

        Protons ($E > 1$ Mev), $J_o \sim 10^7/cm^2$-sec

        Protons ($E > 75$ Mev), $J_o < 0.1/cm^2$-sec

B.   <u>PROTONS IN LOWER EDGE OF INNER ZONE</u>

    $J(E)\, dE \sim E^{-1.8}\, dE$, for $75 < E < 700$ Mev

C.   <u>PROTONS AT OUTER EDGE OF INNER ZONE</u>

    $J(E)\, dE \sim E^{-4.5}\, dE$

D.   <u>ELECTRONS IN LOWER PORTION OF INNER ZONE</u>

    $J(E)\, dE \sim \mathrm{Exp} \left\{ -\dfrac{E}{160} \right\} dE$

    (E in Kev), for energy range $E > 40$ Kev

E.   ELECTRONS IN HEART OF OUTER ZONE

$$J(E)\, dE \sim E^{-1}\, dE$$

for energy range $40 < E < 150$ Kev

$$J(E)\, dE \sim E^{-5}\, dE$$

for energy range $300 < E < 5000$ Kev

F.   PROTONS IN HEART OF OUTER ZONE

$$J(E)\, dE \sim \mathrm{Exp}\left[-\frac{E}{100}\right]\, dE$$

E in Kev, for energy range

$100 < E < 5000$ Kev

Table IV ARTIFICIAL RADIATION BELT

EXPLOSION	LOCALE	TIME	YIELD	ALTITUDE
ARGUS 1	South Atlantic	August 27, 1958	1 Kt	300 Miles
ARGUS 2	South Atlantic	August 30, 1958	1 Kt	300 Miles
ARGUS 3	South Atlantic	Sept. 6, 1958	1 Kt	300 Miles
STARFISH	Johnston Island Pacific Ocean	July 8, 1962	1.4 M	400 km
USSR	Siberia	Oct. 22, 1962	Several Hundred Kt	?
USSR	Siberia	Oct. 28, 1962	?	?
USSR	Siberia	Nov. 1, 1962	?	?

After W. N. Hess, etc., Review of Geophysics, Vol. 3, No. 4, Page 544, November 1965

energetic protons and electrons. A good correlation between positions of high auroral display luminosity and electron flux concentrations have been shown. A belt of trapped soft radiation, which may be connected to the auroral zones has been observed beyond the normal Van Allen belts.

c. Artificial Radiation Belt - One of the original purposes of nuclear detonation was to inject fission fragments at such high altitudes that their β-decay $(n \rightarrow p + \beta^- + \bar{\nu})$ electrons might be trapped. The reason for doing this was to study the source and loss mechanism of the Van Allen belts by using simulated controllable radiation belts. However, it turns out that these artificial belts resulting from some of these tests (such as the Starfish 1962) persist and that they actually contaminate the natural Van Allen zones. Since such artificial belts will last for about ten years, they should be taken into consideration for the formulation of a SEMOS concept. Some of these tests are listed in Table IV.

d. Cosmic Rays consist of atomic nuclei moving with relativistic velocities. The most energetic of these particles have energies $\sim 10^2$ Bev, far beyond any produced by particle accelerators (~ 10 Bev) or by any other natural source. They cause sporadic interference with radio communications and significant radiation dose to man even at sea level. They may be divided into two groups according to their origin: namely, solar cosmic rays and galactic cosmic rays. The former was mentioned in Section IV. A.5 and will not be repeated here.

Galactic cosmic rays are composed of atomic nuclei whose relative abundance is roughly similar to that of the universe as a whole. Thus the major constituents of these galactic cosmic rays are protons, α - particles and heavier nuclei up to Z = 28. The origin of the galactic cosmic rays is highly uncertain, and their intensity is essentially isotropic. It has been found that the energy spectrum of the protons (94% at 2.4 Bev per nucleon) over a wide range of

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energies can be represented by a power law. Thus, if $J (\geq E)$ is the flux of protons having total energies greater than E, then $J (\geq E) = C E^{-\gamma}$ for an energy range of 1 Bev - 10^{10} Bev, where γ varies from about 1. 4 near 1 Bev to 2. 1 near 10^{10} Bev and C increases from about 5×10^3 to 10^7 over the same energy range.

The intensity of galactic cosmic rays is modulated by solar corpuscular radiation (i. e. , solar winds and solar cosmic rays). The enhanced solar winds during periods of maximum solar activity carry a more intense (relative to the quiet sun) interplanetary magnetic field that shields against the galactic cosmic rays more effectively, and the galactic cosmic ray intensity decreases. During periods of minimum solar activity the intensity of the solar wind and its associated interplanetary magnetic field are lower, and the galactic cosmic rays can penetrate more readily.

In addition to the eleven year modulation of galactic cosmic ray intensities by the sun, there are short term variations associated with the enhanced emission following many (not all) solar flares. This decrease of galactic cosmic ray intensities due to this short term modulation is the famous Forbush decrease.

7. Micrometeorites - Meteoroids are astronomical bodies which travel in generally wide and eccentric orbits about the sun. Although a few are large and weigh many tons, the vast majority are too small to produce either visual or radar images when striking the Earth's atmosphere. These micrometeorites range in size down to a few microns. For these smaller particles, solar electromagnetic radiation can exert enough pressure to essentially sweep the particles from the solar system. Since there is thus a continual loss of micro- meteoritic material in space because of these radiation effects, there must be a continuous replenishment. Otherwise, they would have dis- appeared from interplanetary space long ago. It is suggested that cometary debris, asteroidal collisions, and meteor impacts on the moon contribute material.

Current estimates of the micrometeorite flux in near-Earth space exhibit a number of differences. Rocket probes, satellites,

space probes, and extrapolations from radar and visual data have been used to generate the various micrometeorite models. Further correlations are necessary.

Studies of the zodiacal light indicate that a concentration exists in the plane of the ecliptic, extending inward to the sun. It is expected that planetary gravity increases the concentration near the planets by pulling the particles into capture orbits. Thus, it has been postulated (but also questioned)that there is a dust blanket around the Earth.

Meteor showers are a phenomenon which tends to recur on an annual basis. It is believed these swarms represent the debris of old comets in their former orbits.

It has been noted that the total integrated flux of meteors (bodies more massive than 10^{-6} gm) through a given volume of cislunar space in the course of a year is roughly half due to swarms, and half due to sporadic meteors of purely isotropic distribution. Moreover, the sporadic meteors tend to be, on the average several orders of magnitude more massive.

8. Radio Noise and Interference - Background noise in the space environment limits the minimum signal level that any receiving system can detect. Below approximately 20 Mc/s, considerable noise is caused by both atmospheric and man-made generators. Up to 1000 Mc/s, cosmic noise becomes the limiting factor although man-made interference is important up to several hundred megacycles. Above 1000 Mc/s, the cosmic background drops to very low intensities and the thermal noise in the receiving equipment predominates. At extremely high, and currently unusable frequencies greater than 10 GHz the inherent emissions from atmospheric oxygen and water vapor become the dominating noise source in the near-Earth space. Also, emission from galactic hydrogen at 21 cm is important.

In addition to the relatively uniform noise sources discussed above, large discrete sources of radiation other than the sun exist in the universe. These emissions are associated with remnants of supernovae, galaxies in collision, other galaxies, Jupiter, and Saturn.

The Sun is an important source of radiofrequency radiation. Part of the energy is thermal in origin and follows the Planck distribution law. Superimposed on this "black body" radiation are discrete emissions which vary in intensity, frequency and polarization. Different layers

of the Sun and entities on it are characterized by different radio frequency emissions. Sunspots, filaments, the coronosphere, flares and the photosphere all generate their own characteristic emissions at wavelengths which have been found to range from 10^3 meter to 1 mm. These signals are often sporadic and are superimposed on the background black body signal from the Sun.

9. Geomagnetism - The gross features of the geomagnetic field are similar to those of a uniformly magnetized sphere. In detail, however, such a simple model is inadequate. For a recent summary, see Item 52 of the Bibliography. The intricate irregularities and variabilities are too involved to be discussed in detail here. The main magnetic field is commonly supposed to originate by dynamo action in the fluid motion of the molten metallic core of the Earth. This motion is not stable and changes slightly from year to year.

Superimposed on this secular variation, transient variations occur which are produced chiefly by the interactions of the solar plasma, solar cosmic rays with the geomagnetic field. The high electrical conductivity of the region surrounding the Earth requires the adoption of a hydromagnetic approach to the analysis of the phenomena.

Geomagnetic storms are disturbances which occur in the magnetic field coincident with solar activity. Their commencement is usually very sudden, signalling the impact of the solar plasma wave front on the geomagnetic field. The effect of the impact is propagated to the lower ionosphere by hydromagnetic waves. Large amplitude fluctuations in local magnetic flux occur due to major instabilities in the flow of the solar wind past the geomagnetic field. Recovery usually takes one to three days.

B.   MONITORING PARAMETERS

The specific parameters which must be measured to confidently develop a monitoring system are not defined precisely at this time. Because of the vast lack of definitive knowledge of the Earth's environment, the distinction between operational and scientific parameters remains fuzzy. For the purposes of this study the monitoring parameters were categorized as shown below. This breakdown is arbitrary and is not meant to imply any suggested system division.

UPPER ATMOSPHERE DENSITY

    a.   Variation in an Earth-centered coordinate system (altitude, latitude, and longitude.

    b.   Correlation with solar cycle, magnetic storms and flares

    c.   Variation in constituents

    d.   Diurnal and annual variation

    e.   Effect on reentry corridor and landing "footprint" of a spacecraft.

IONIZATION

Ionosphere:

    a.   F region electron concentration

    b.   Diurnal and seasonal variation

    c.   Correlation to sunspot cycle, magnetic storms

    d.   Positive ion identification (O^+, N^+, etc.)

Protonosphere:

    a.   Proton concentration

    b.   Electrical conductivity

    c.   Altitude variation

CORPUSCULAR RADIATION

Van Allen Belt:

a.   Particle flux versus altitude, bremsstrahlung

b.   Van Allen belt definition

c.   Correlation to sunspot cycle, magnetic storms

d.   Diurnal and seasonal variations

e.   Correlation to magnetic field

Solar Flare:

a.   Particle flux

b.   X- and Gamma-Ray Flux

c.   Intensity and Direction as a Function of Time

d.   Correlation to Earth and B-L Coordinates

e.   Correlation with magnetic field variations

Cosmic:

a.   Particle abundance and energies

b.   Proton flux versus energy

c.   Behavior in magnetic field, latitude distribution

d.   Albedo neutron flux versus energy

e.   Meson flux, lifetime, energy

METEOROIDS AND MICROMETEORITES

a.   Particle size, energy, direction of motion, mass, flux

b.   Correlation with Earth coordinate system

c. Periodic swarms and sporadics

d. Particle density, composition, radioactivity level

RADIO NOISE

a. Level versus frequency range

b. Correlation to diurnal, annual, sunspot cycles

c. Cosmic noise source identification

d. Solar noise isolation

e. Transmission characteristics of atmosphere

f. Man-made radio noise (from ground)

THERMAL RADIATION

a. Solar irradiance versus wavelength

b. Solar constant versus sunspot cycle

c. Earth albedo measurements versus geography

d. Diurnal and annual variations

e. Earth thermal emmission versus geography

MAGNETIC FIELD

a. Geomagnetic

b. Solar System

c. Field distribution in B-L and Earth-centered coordinates

d. Correlation to diurnal and sunspot cycles

e. Interactions of solar system and geomagnetic fields, including wakes, MHD shocks, etc.

f. General magnetohydrodynamic characteristics.

g. Geomagnetic and solar magnetic storm features

METEOROLOGY

a. Surface temperature, rain and snow cover, flooding, etc.

b. Atmospheric winds, clouds, water content, etc., versus time.

c. Front locations, movement, cloud types, etc., including vertical structure.

d. Localized storm conditions, intensity, movement, etc.

e. Ozone distribution, upper atmosphere constituents including vertical structure.

f. Heat balance and net radiation.

Classification of these parameters into three operational requirements are shown in Table V. For the purposes of this study, the following definitions of these requirements are presented.

Emergency - environmental parameters which must be monitored continuously to insure the safety of men in space systems. Warnings of hazardous conditions are the intended purpose.

Operational - environmental parameters which should be monitored to assist in the satisfactory completion of manned space flights, the forecast of communication parameters, and other space-related activities. The status of space conditions and recommendations for operational changes are the intended purpose.

Scientific - environmental parameters which can be monitored to obtain data contributing to the understanding and evaluation of the space environment and the attendant functions of instrumentation development, procedures testing, and systems development (stabilization, calibration, data storage, etc.). Data collection, research, and development are the primary purposes.

The classification of the measurement parameters can further be analyzed according to the different criteria for the three operational requirements just defined. Briefly these criteria are enumerated in Table VI.

Table V   CLASSIFICATION OF SPACE MONITORING PARAMETERS

MEASUREMENT	REQUIREMENT			
	Emergency	Operational	Scientific	
			Research	Development
1. Atmospheric Density	x	x	x	x
2. Ionization				
Ionosphere		x	x	x
Protonosphere		x	x	x
3. Corpuscular Radiation				
Van Allen		x	x	x
Solar Flare	x	x	x	x
Cosmic			x	x
4. Meteorites and Micro-meteorites	x	x	x	x
5. Electromagnetic Radiation				
Radio Frequencies		x	x	x
Solar X-rays	x	x	x	x
Optical, UV, Visible and IR		x	x	x
6. Magnetic Fields		x	x	x
7. Meteorology	x	x	x	x

Table VI   PARAMETER COMPARISON

PARAMETER	Emergency	Operational	Scientific	
			Research	Development
Reliability	Very high	High	High	High
Accuracy	Moderate	Moderate	Very High	Moderate
Data readout	Immediate-ly	Soon	Can be Stored	Can be Stored
Cost	Whatever necessary	Low	Moderate	Moderate
Data retention	Little	Little	Complete	Maybe partial
Data usage	Flight control center and astronauts	Flight control center and Earth oriented users	Scientific community	Scientific community and Engineers

These classifications are directly related to the purposes of the systems considered. Thus, the concern of the safety of astronauts permits the acceptance of the high cost which necessarily accompanies the very high reliability needed in emergency systems. Because the purpose of emergency systems is warning of hazardous conditions, data readout must be immediate, and only moderate amounts of data storage can be used. The requirements of operational systems are similar, although the very high cost possibly associated with emergency systems cannot be justified. One can therefore expect a lower, but still relatively high, reliability.

In considering the requirements of the scientific classification tabulated above, the most important difference is the treatment of data. Compared to emergency or operational systems, complete retention of research data is almost always required. For developmental purposes, the nature of the system objectives permits a slight compromise in accuracy and data retention.

There must always be a clear distinction between "data" and "information". A scientific system collects and transmits data because some interesting scientific information might be contained in what might appear to be noise or errors. An operational system must be based on prior decision about what is worth measuring, and how the measurements will be processed. A SEMOS system will require a multiplicity of measurements. An attempt to store and transmit all the data gathered would serve to defeat the purposes of the system by overloading the available communications channels. The data should be processed for its significant information content before it is transmitted. This can be done partly by the sensing instruments themselves, if they are designed with internal discriminator levels, count accumulators, background level eliminators, etc.; and in part by data processing systems built into individual SEMOS buoys, satellites or probes.

It can be seen that wide variances exist in the type of data which would be utilized for the different requirements. This implies that a detailed and extensive analysis of the instrumentation systems is required to intelligently develop an operational SEMOS concept.

C.   EXISTING EXPLORATORY PROGRAMS

The identification and investigation of the Earth's space environment has, up to the present time, been undertaken almost completely by a number of relatively small satellite systems. The Explorer series of satellites, beginning with the successful launch of Explorer I in 1958, has been the most longlived and successful program. This first Explorer discovered the Van Allen radiation belts. Today, the study of this natural environmental phenomenon plays an important role in the development of our manned space programs.

With the advent of larger launch systems and our increased confidence in developing sophisticated space platforms, the trend in space environment investigation is to the complex "observatory" family of spacecraft. The smaller, less expensive satellite programs are becoming of somewhat less interest and are gradually being turned over to the universities. The University Explorer, typical of this new approach, has already been funded and some work has begun. It is anticipated that four launches a year will be scheduled indefinitely. This evolution in the investigation of the space environment is significant in the study of a SEMOS concept. As the academicians of the universities assume the responsibility for these programs, the usefulness of their results to an operational system will be diminished. This will be due in part to a different exploratory approach, although the primary incompatibility will be the proprietary rights to the data granted by NASA. For example, on the "Observatory" series of spacecraft (OGO, OAO, etc.) where NASA is the program director and a commercial organization is the prime hardware contractor, the experimenters supplying the individual instruments have proprietary rights to the scientific data for a year.

The following tables, Tables VII through XIV, describe briefly the current and planned satellite programs to identify and investigate the near-Earth space environment. Numerous satellites launched since 1958 on completed programs are not listed herein for sake of clarity. We are concerned only with existing plans and schedules related to the study of a SEMOS concept. Thus, only those programs involved in investigating the terrestrial space environment are discussed. These charts are intended to be as current as possible, but space systems are being developed continuously and some omissions of new satellites may have occurred.

Table VII   UNMANNED SATELLITES

ATS   Applications Technology Satellite, NASA-Goddard,
                     Flight Test communication and meteorological equip-
                     ment.   Test bed for gravity gradient experiments.
                     Weight 780 lbs.   Atlas Agena booster.   Hughes
                     prime contractor.

                     Five launches programmed beginning in 1966.   Two
                     flights low Earth orbit, two flights in medium orbits,
                     one flight synchronous orbit.

SUNBLAZER   Measure electron density in the near-Sun regions.
                     Weight 15 pounds, Scout booster.   MIT contractor
                     to NASA-Langley.

PEGASUS   Measure effects of meteoroid damage on materials.
                     Over 200 sq. ft. of exposed area;   weight 3400 lbs.
                     NASA-Marshall.   Fairchild-Hiller, prime contractor.

                     PEGASUS 1   Feb '65)
                     PEGASUS 2   May '65)   Program complete
                     PEGASUS 3   July '65)

Table VIII JOINT FOREIGN/U. S. PROGRAMS

ALOUETTE   Canada-Ionospheric studies. Weight 320 lbs.,
                 625 n. mile orbit. Booster Thor-Agena B. NASA-
                 Goddard and Canadian Defense Research Establish-
                 ment.

                 Alouette 1   Sept. '62 Swept-frequency topside sounder
                 Explorer 20   Aug '64 Fixed-frequency topside sounder
                 Alouette 2)
)   Nov '65 Dual launch
                 Explorer 31)
                 Explorer -   Planned '66 or '67

ISIS   "International Satellite for Ionospheric Studies" - Canada.
                 Study make-up of ionosphere; ambient electron density
                 and temperature. Boosters Thor/Agena or Delta.
                 Weight 350 lbs. Follow-on to Alouette program.

                 ISIS-A   Planned '67
                 ISIS-B   Planned '68
                 ISIS-C   Planned '69

ARIEL   United Kingdom - Approximately 150 lbs, Scout booster.
                 450 km circular orbit. Measure large-scale noise
                 sources in the galaxy and the intensity of VLF radiation.

                 Ariel I   April '62
                 Ariel II   March 1964
                 Ariel III   Late '66 launch planned

SAN MARCO   Italy - Measure aerodynamic drag in equatorial orbit.
                 Ionospheric propagation studies using a beacon. Weight
                 250 lbs. Scout booster.

                 San Marco I   Dec. '64

Table IX   EUROPEAN SPACE RESEARCH ORGANIZATION (ESRO)

HEOS-A   "Highly Eccentric Orbiting Satellite". Measure cislunar
               magnetic fields, cosmic rays, and solar winds.

LAS   "Large Astronomical Satellite". Complementing NASA's
               OAO series.

ESRO I   Scout launches in 1967. To study northern polar iono-
               sphere during winter. Scout booster. Weight 154 lbs.
               930 mile apogee, 170 mile perigee.

ESRO II   Measure particle and proton levels. Polar orbit of 684
               mile apogee, 218 mile perigee. Scout launch planned
               for March 1967.

TD-2   Solar-ionospheric experiments.   Weight 880 pounds;
               near-polar orbit of 620 mile apogee and 218 mile perigee.
               Planned launch in early 1969.

Table X   FRENCH   PROGRAMS

A-1   Launched November 26, 1965, Diamant, 88 lb test
                        satellite, 1110 n. mile apogee, 315 n. mile perigee.

D-1A   Earth's magnetic fields, check French tracking
(Diapason)   stations. Diamant booster apogee 1710 miles,
                        perigeee 312 miles, inclination 34.04°, launched
                        on February 17, 1966.

D-2   Study distribution of geocoronal atomic hydrogen,
                        measure absorption of Lyman-alpha lines by optical
                        resonance methods. Weight 75 pounds, 550 mile
                        apogee, 275 mile perigee. Solar orientation to $\pm$15
                        minutes of arc. Diamant booster launch planned in
                        1968.

D-3 (EOLE)   Query 500 or more constant pressure balloons sent
                        aloft around equator to gather meteorological data.
                        Test feasibility of this system. Planned for 1967
                        launch on Diamant booster.

FR-1   Measure electronic and magnetic components of ultra
                        low frequency radio emissions in the ionosphere. Orbit
                        apogee 480 n. miles, perigee 462 n. miles, inclination
                        76°. Launched December 6, 1965, on Scout booster
                        donated by NASA. Weight 135 pounds.

Micrometeorite   German probe to use French Centaure rocket. Collect
Collector   micrometeorites above 80 km and return to Earth.

Table XI EXPLORER SERIES
(Orbits 150 to 9000 n. Miles, Elliptical and Circular)

Energetic
Particles
Explorer

Study natural and man made radiation belts. Weight 100 lbs. Delta booster. NASA - Goddard.

Explorer 1	Jan '58	Discovered Van Allen belts
Explorer 3	Mar '58	
Explorer 4	July '58	Project Argus radiation shells
Explorer 6	Oct '59	Magnetic field and storms, solar flares, radiation belts, micrometeorites
Explorer 10	Mar '61	
Explorer 11	Apr '61	Gamma ray counter
Explorer 12	Aug '61	Revealed Solar Wind
Explorer 14	Oct '62	
Explorer 15	Oct '62	
Explorer 26	Dec '64	

Micrometeorite
Explorer

Supply data on micrometeorite hazard using exposed sensor surface area of 30 square feet. Weight 300 lbs. Scout booster. NASA-Langley.

Explorer 16	Dec '62	Beryllium-copper surface
Explorer 23	Nov '64	304 Stainless surface

Atmosphere
Explorer

Study composition, density, pressure, and temperature of Earth's upper atmosphere. Study chemistry of ionosphere. Weight 400 lbs. Delta booster. NASA-Goddard. Budd Company prime contractor.

Explorer 8	Nov '60	Ionospheric data
Explorer 17	Apr '63	Discovered belt of neutral Helium.
Explorer -	Planned '66 launch	

Table XI Continued

| Interplanetary Explorer (IMP) | From deep Earth or lunar orbits, study cislunar radiation environment over significant portion of solar cycle. Study interplanetary magnetic field and Earth's magnetosphere. Develop solar flare prediction capability and assess radiation hazard for Apollo. Weight 135 lbs in Earth's orbit; 181 lbs in lunar orbits. Booster TAD; NASA-Goddard. |

Explorer 18   Nov '63   IMP-A
Explorer 21   Oct '64
Explorer 28   May '65
(Lunar)   Second half '66, 2 launches
(Lunar)   '67
(Earth)   '67, 2 launches

| Radio Astronomy Explorer | Determine, as a function of frequency, position, and time the direction and intensity of celestrial radio signals below 20 mc. Four 750 ft extendable antennas. Observe radio storms generated by solar particles interacting with radiation belts. Study solar radio bursts and Jupiter emissions. Orbit 3200 n. miles. Weight 280 lbs. TAD booster; NASA-Goddard. |

RAE-A   '67
RAE-B   '67

| Air Density Explorer (INJUN) | Measure latitude variations in composition, density, and temperature. Study source of atmospheric heating. Weight 78 to 90 lbs. Scout booster. NASA-Langley. Bendix, spacecraft contractor. |

Explorer 9   Feb '61
Explorer 24)   Nov '64 Dual Launch
Explorer 25)
    -          '66   Chemistry of Ionosphere

Program splitting into two parts:

1. Air Density Sphere (12 ft inflatable); NASA-Langley. To find variations of density and temperature as a function of latitude. Find sources of atmospheric heating.

2. INJUN, University of Iowa, to study Van Allen belt phenomena. Part of "University Explorer", see below.

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Table XI Continued

University	Series of small satellites made available to universi-
Explorer	ties for space research. Weight 100 to 125 lbs.
Program	Scout booster. NASA - Langley and NASA - Wallops.

OWL - A)	'67	Auroras and airglow	Rice University
OWL - B)			
INJUN	Late '67 or '68		University of Iowa
MICHAEL	Early '68 Aeronomy		University of Mich.

Table XII METEOROLOGY SATELLITES

NIMBUS   NASA-Goddard. Vidicon cameras for cloud data, radia-
                     tion sensors at various resolutions and spectral ranges
                     for heat balance, temperature, and cloud cover. Auto-
                     matic picture transmission system. High resolution
                     infrared radiometer for night cloud cover pictures.
                     Weight approximately 950 pounds, 500 mile near polar
                     orbit. TAT-Agena booster; GE integration and testing
                     contractor.

NIMBUS 1	Aug '64 Elliptical orbit	(NIMBUS A)
NIMBUS 2	1966)	(NIMBUS C)
NIMBUS 3	1967) Planned Launches	(NIMBUS B
NIMBUS 4	1968-1969	

SMS   Synchronous Meteorological Satellite, NASA programmed.
                     To provide continuous monitoring of short-lived storms
                     and cloud cover and of the whole disc of the Earth. Size
                     undetermined, synchronous orbit. Atlas-Agena or Atlas-
                     Centaur. Hardware funding expected in 1967.

TIROS   NASA-Goddard program for TV pictures of cloud cover.
                     Scanning and non-scanning radiation sensors; narrow,
                     medium, and wide angle cameras. Weight 285 to 300 lbs;
                     Delta booster; 450 n. mile orbit. RCA prime contractor.

TIROS 1 through 7		1960 through 1963 - Development Launches
TIROS 8	Dec'63	Automatic picture system
TIROS 9	Jan'65	Cartwheel configuration
TIROS 10	July '65	
TIROS J	Last half '67	IR cloud mapping

TOS   Tiros Operational System - To afford global weather in-
(Now designa-   formation on a continuous basis. Polar, sun synchronous
ted as ESSA   orbits at 400 n. miles and 750 n. miles. Automatic picture
family)   transmission and advanced vidicon systems planned.
                     Weight 300 pounds; Delta booster. RCA prime contractor.

TOS 1 Feb '66 - ESSA I new designation
TOS 2 Feb '66 - ESSA II new designation
TOS 3 Mid '66 planned

Table XIII   OBSERVATORY SPACECRAFT FAMILY
NASA-GODDARD

OSO   Orbiting Solar Observatory
         Map solar disk in UV and X-ray; corona in white light; celestial
         sphere in UV and gamma rays; polarized and unpolarized zodiacal
         red and blue light. Pointing accuracy of $\pm$ 1 arc-min. Circular
         orbit 300 to 330 n. miles. Weight 540 lbs. Delta booster. Ball
         Bros. contractor.

OSO-1	Mar '62	
OSO-2	Feb '65	In operation
OSO-C	Aug '65	Booster failure; unsuccessful
OSO-E1	Due mid '66	
OSO-D	Due late '66	
OSO-E)		
OSO-F)	Planned	
OSO-G)		

         "Collects data needed to establish a solar-flare prediction system
         for Apollo" according to Space/Aeronautics, Vol. 45, No. 1,
         January 1966.

OGO   Orbiting Geophysical Observatory
         Observe Earth, Sun, and space simultaneously for correlated
         studies of particles and fields within Earth's magnetosphere,
         atmosphere, and cislunar space. Orbits are highly eccentric
         (150 to 90,000 n. miles), polar circular (150 to 500 n. miles),
         and polar eccentric (under study). Weight 1000 to 1500 lbs.
         Atlas/Agena booster, highly eccentric; thrust augmented Thor
         booster, polar circular. TRW/Systems, prime contractor.

EGO-1	Sept '64	Partial success
POGO	Oct '65	Partial success (OGO-2)
OGO-B	Due first half '66, eccentric orbit	
OGO-D	Due late '66, polar circular orbit	
OGO-E	Due '67, eccentric orbit	
OGO-F)		
OGO-G)	Planned 1968	

         The eccentric orbiters study the magnetosphere and cislunar
         space. The polar orbiters study the Earth's atmosphere.

Table XIII Continued

OAO   Orbiting Astronomical Observatory
           Conduct highly directional astronomical observations, mostly
           in UV. Secondary X-ray experiment on OAO-C. Circular
           orbits, 430 to 450 n. miles, weight 3884 lbs. Atlas/Agena
           booster. Grumman, prime contractor.

           OAO-A1   Early '66 Study stars and nebulas (U. of Wisc.)
           OAO-B   Late '66   Telescope, 36" fl (Goddard)
           OAO-A2   1967   Sky map in 4 UV ranges (Smithsonian)
           OAO-C   1968   Spectral absorption of interstellar
                                  medium and X-ray experiment
                                  (Princeton)

ORAO   Orbiting Radio Astronomy Observatory - Under study but not
           yet programmed.

Table XIV   AIR FORCE PROGRAMS

Because of security reasons and lack of time in this liaison effort, the following list is known to be incomplete. In general, the investigation of the space environment within the USAF to develop systems for the protection of man is the responsibility of the Aerospace Medical Research Laboratory of the Aerospace Medical Directorate. The Office of Aerospace Research (OAR) was authorized by the U.S. Air Force/DOD as the agency to provide launch vehicles and satellite carriers for all space research by DOD agencies.

FESS — "Flight Experiment Sub-Satellite" program - Experimentally assess assumptions made in the Computer Analysis of Radiation Shielding (CARS) program. Launched as OV1-2 on Titan III booster.

FARO — "Flare Activity Radiobiological Observatory" - to develop a solar flare detection system. Orbit in the 200-400 mile range. Several contractors, including Bendix, Northrop Space Laboratories, etc.

| OV1-9 | Nov '66 Planned launch |
| OV1-11)
OV1-12) | May '67 Planned launch |

ANNA IB — Geodetic research satellite for military purposes. Measure strength and direction of gravitational field, locate positions on Earth's surface, locate Earth's center of mass. Weight 350 lbs; Thor-Ablestar booster. Johns Hopkins Applied Physics Laboratory prime contractor.

The preceding tabulations indicate that much exploratory work is currently underway covering the spectrum of environmental parameters of interest. To better visualize these programs, the following chart, Figure 16, is presented. This chart indicates the scope of the investigative work and the approximate scheduling of those programs currently funded or firmly committed. Thus, although the chart does not continue beyond 1969, it is anticipated that considerable exploratory activity will eventually occur in that time frame. An increasing role of the universities is to be expected together with the emergence of foreign agency participation.

The parameters selected for comparison indicate the general categories of the exploratory programs. The breakdown is arbitrary and is not intended to imply an organizational or program distinction maintained by the controlling agencies. Actually, a review of the Table will indicate the broad overlap of the programs which exist. This characteristic requires close cross-correlation of the experiments and intelligent integration of the data.

To provide a national focal point for this purpose, the Environmental Data Service of ESSA has been recently established. This agency will collect and publish worldwide environmental data for industrial or scientific use. An aeronomy and space data center will be established to headquarter this service.

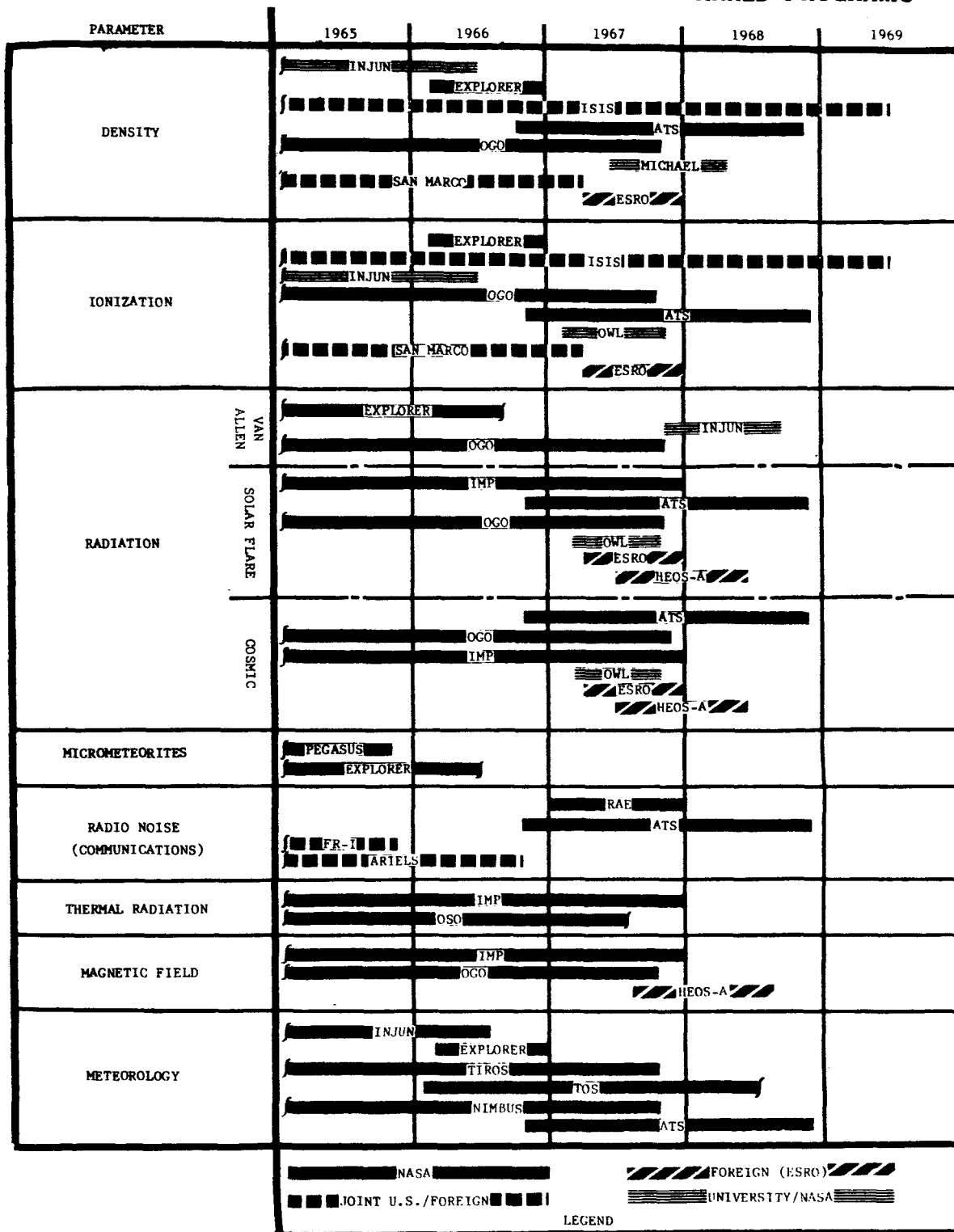# SPACE ENVIRONMENT INVESTIGATION-CURRENT AND PLANNED PROGRAMS

Figure 17

SECTION V. CONCLUSIONS AND RECOMMENDATIONS

A.   CONCLUSIONS

1.   <u>Need</u> - This report shows there may be a need for a space environment monitoring system as envisioned by MSFC to operate on a continuous, real-time basis. Because of the interest of ESSA in a meteorological observing system, the integration of the space monitoring requirements into one total system under operational control of ESSA appears reasonable at this time. A cost effectiveness advantage will result with no compromise in operational flexibility.

The developmental phases of operational unmanned meteorological systems are currently vested in NASA's Goddard Space Flight Center through their participation with ESSA in TIROS, NIMBUS, and the ESSA satellites. The responsibility of extending this development to include the considerations of man in orbital stations necessarily rests with NASA. The stated scope of the Apollo Applications Program studies currently underway at MSFC appear to include what can be envisioned as the developmental phases of a SEMOS study. The inclusion of space and meteorological monitoring requirements as a facet of the AAP analyses thus represents a logical beginning for a SEMOS feasibility study. This can be accomplished with a minimum of program and budget modifications.

2.   <u>Role of Man</u> - It was shown in this report that man can take an important place in an operational system by applying his intuitive reasoning, learning, and observational capabilities. An intelligent development of an optimized man-machine entity, although limited in some degree, will maximize the benefits to be derived by including man in the system. That he must be present all the time was not clearly shown in this study, and perhaps the "optimized man-machine entity" is in reality a semi-manned system wherein human occupancy of the orbital stations is intermittent. Further clarification of this aspect of a SEMOS concept is required.

3.   <u>Instrumentation and Data Handling</u> - These requirements in an operational system such as SEMOS were shown to differ in a number of respects from those of the scientific community which up to now has

dominated this discipline of the space efforts. These differences are significant enough to become important aspects of the SEMOS studies. The work completed in the study reported herein indicates that before studies of the instrumentation hardware can be initiated, an understanding of the data handling requirements is necessary. We must know what it is we intend to measure and have a reasonably good idea of the properties of the information that will be received. Further extensive study work in this area is necessary which carefully considers the interchangeability of packages in subsystems to permit operational flexibility.

4. <u>Warning Systems</u> - The imminence of the Apollo orbital and lunar flights has led to the development of rudimentary warning systems within NASA and the USAF. These are not space-based monitoring systems, but rely on ground-based observations of the Sun to provide empirical short range predictions of solar flare hazards. The NASA/ESSA program has been established utilizing SPAN (Solar Particle Alert Network) and solar flare predictions of the Space Disturbances Group at the Intitute for Telecommunication Sciences and Aeronomy. For the USAF, thrice daily flare predictions have been made for two and one-half years by the Air Weather Service.

These facts require a reevaluation of the original objectives of the SEMOS study which were developed without the complete understanding of these efforts to develop operational warning systems. It is difficult, at this time, to envision a SEMOS concept which would operate independently of these ground based systems. It is therefore concluded, that further efforts by MSFC should be directed toward the study of the existing warning systems to determine their eventual role.

5. <u>Further Study</u> - In addition to those areas discussed above, continuing efforts should center around the aspects of launch system integration, system operations, applicability of AAP, and payload development for an operational space and meteorological monitoring system. Detailed recommendations for continuing these studies are presented in the next section of this report.

A number of secondary conclusions, taken in context with the general conclusions stated above are presented below:

6. <u>Liaison With USAF</u> - The Air Force will, for security reasons, probably not find it practical to depend on a NASA warning for monitoring system. However, they will be able to provide appropriate data collected by their Air Weather Service as a contribution to NASA's system.

7. <u>NASA Coordination</u> - Detailed coordination between the NASA Centers at a high level is necessary to insure that conflicts and duplications do not occur and that the scientific requirements and contributions to an operational space environment monitoring system will be recognized. The specific missions of the various systems must be well defined to assure other centers that their activity in the space environment program will not be curtailed due to the emergence of SEMOS.

8. <u>Manned Stations</u> - Permanent manned stations in geostationary orbit appear to be impracticable, since the radiation shielding requirements will lead to impossible payload weights. Semi-permanent manned stations in the synchronous orbit could be considered, but the cost effectiveness test should be the primary basis of any use of man in space. Permanently manned stations in low Earth orbits are feasible, but their practicality is still to be decided by the later phases of this SEMOS study.

B. <u>RECOMMENDATIONS</u>

A follow-on phase to this study, if initiated, should primarily consider the following aspects of a SEMOS concept:

1. Contributions of the AAP studies and subsequent flights in terms of launch system integration, systems operation, sensor and instrumentation development, data handling concepts, and role of man.

2. Integration of the SEMOS concept with the existing NASA/ ESSA warning system being developed at Houston and Boulder. Further liaison and analysis would indicate the contributions orbital systems would make to enhance the warning networks and provide operational data such as atmospheric transmissibility, density profiles, radiation levels, etc.

3. Requirements, concepts, hardware, and developmental program of the operational instrumentation (as opposed to the scientific instrumentation in general use). The correlation of these systems to the data handling system including real-time considerations, data interpretation, and environment forecast dissemination.

The following is a brief description of the recommended continuation of this study:

Phase II:

Purpose - Definition of the requirements, evolution, and constraints of a system leading to manned or semi-manned environmental monitoring missions considering the existence of the elementary ground based warning networks in development and the role of the Apollo Applications Program currently under study. Development of a preliminary concept of possible operations and systems.

Procedure - Utilizing the results of Phase I, select directly appropriate organizations for further liaison and integration discussions. Consider the existence of the NASA/ESSA ground based warning system of ITSA, based at Boulder, Colorado. Considerable correlation will be maintained with ESSA in Washington, D. C. Specifically, the missions, programs, and plans of the Environmental Data Service, Institutes for Environmental Research, and National Environmental Satellite Center will be understood and integrated into the study. Particular attention will be paid to the instrumentation and data handling requirements of the operational aspects of the SEMOS concept and the possible utilization of AAP flights to assist in the development of hardware to meet these requirements. Develop the mission objectives, system requirements, and system constraints of the SEMOS concept based on the above analyses. Consider the evolutionary development of the system accounting for the AAP schedules and capabilities. Include such alternatives as separate unmanned buoys, manned or unmanned master control stations, deep space satellite systems, or combinations of these. Conduct mission and operations analyses, interface analysis, launch system integration studies, and data handling systems. Iterate these procedures as necessary to satisfy completely the objectives and requirements being considered.

Expected Results - A preliminary definition of a manned and/or unmanned environmental monitoring system including, or integrated with, those ground warning networks currently being developed. An evolutionary developmental program within the context of the Apollo Applications Program including subsystem, instrumentation, and data handling details.

Phase III:

Purpose   -   Develop a conceptual design of a manned,
semi-manned, and/or unmanned monitoring system.

Procedure   -   Utilizing the preliminary findings of
Phase II, investigate the technical aspects of the design
of the monitoring system in detail.   Conduct mission and
operations analyses, launch system integration studies, and
technical analyses to develop a conceptual design of the
selected system.   Include considerations of human factors,
subsystem performance, system integration requirements,
data dissemination, crew rotation, etc.

Expected Results   -   A conceptual design and operational
plan of a manned and/or unmanned space environment
monitoring system.

APPENDIX

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